5(2)
274-281

KYOTO UNIVERSITY

PUBLICATIONS OF THE SETO MARINE BIOLOGICAL LABORATORY

Vol. V, No. 2

(Article 8 to 18)

JAN 1957
LIBRARY
POFI
FISH & WILDLIFE
SERVICE

SIRAHAMA, WAKAYAMA-KEN, JAPAN
PUBLISHED BY THE LABORATORY
June 1956

CONTENTS

Article		*Page*
8.	**Yamanouchi, T.:** The visual acuity of the coral fish *Microcanthus strigatus* (Cuvier et Valenciennes).	133
9.	**Yamazi, I.:** Plankton investigation in inlet waters along the coast of Japan. XIX. Regional characteristics and classification of inlet waters based on the plankton communities.	157
10.	**Tokioka, T.:** On chaetognaths and appendicularians collected in the central part of the Indian Ocean.	197
11.	**Tokioka, T.:** On chaetognaths and appendicularians collected by Mr. Z. Sagara in the Arafura Sea in May-August 1955.	203
12.	**Baba, K., Hamatani, I. and K. Hisai:** Observations on the spawning habits of some of the Japanese Opisthobranchia (II).	209
13.	**Utinomi, H.:** On some alcyonarians from the West-Pacific islands (Palau, Ponape and Bonins).	221
14.	**Utinomi, H.:** On the so-called "Umi-utiwa," a peculiar flabellate gorgonacean, with notes on a syllidean polychaete commensal.	243
15.	**Tanaka, O.:** The pelagic copepods of the Izu region, middle Japan. Systematic account. I. Families Calanidae and Eucalanidae.	251
16.	**Kuwano, Y.:** Invertebrate fauna of the intertidal zone of the Tokara Islands. XII. Foraminifera.	273
17.	**Ogata, E.:** Noteworthy algae from Takarazima Island.	283
18.	**Umezaki, I.:** On a collection of *Gardnerula corymbosa* (Harvey) J. de Toni.	291
19.	**Record of Works** done at the Seto Marine Biological Laboratory (for 1954).	297

All communications intended for the "Publications" should be addressed to the editor, Dr. H. Utinomi, The Laboratory, Sirahama, Wakayama Prefecture.

THE VISUAL ACUITY OF THE CORAL FISH *MICROCANTHUS STRIGATUS* (CUVIER & VALENCIENNES)[1]

TOSHIHIKO YAMANOUCHI
Member of the Educational Committee of Kyoto Prefecture;
Formerly Lecturer of Zoology at Kyoto University

With 16 Tables and 10 Text-figures

CONTENTS

		Page
I.	INTRODUCTION	133
II.	METHOD	134
III.	VISUAL ACUITY	137
	a) MINIMAL PHYSIOLOGICAL VISUAL ANGLE	137
	b) MINIMAL MORPHOLOGICAL VISUAL ANGLE	140
IV.	DISTRIBUTION OF CONES IN THE RETINA	143
V.	CHANGE OF VISUAL ACUITY WITH AGE	147
VI.	FIGURAL TRANSPOSITION	148
VII.	INTERPRETATION	151
VIII.	SUMMARY	154
	LITERATURE CITED	155

I. Introduction

In angling, fine and transparent fishing line is used to render the drail invisible against the bright water background. This proves without a doubt that fish have a keen sight for external objects. Some fish have indeed relatively large eyes in contrast to their size (Fig. 1). In Japan fine and transparent thread made from the silk gland of the Japanese oak-worm moth is used instead of catgut. Recently, drail made from nylon has also been used. Fine drail made from wild-cocoon silk above mentioned is 0.08 mm in diameter. Whether such fine drail could be seen by fish or not, will be discussed below in VII (Interpretation).

After the pioneer works of HERTER (1929, 1930) on the form perception of fish, BRUNNER (1934) studied the visual acuity of the fresh water fish, *Phoxinus laevis* (Erlitze), by a training method. In his study the limit of visual acuity was determined by training fish to select a fine parallel striped pattern (+) against a gray paper (−) in different light intensities. In this study the coral fish *Microcanthus*

1) Contributions from the Seto Marine Biological Laboratory, No. 274.

strigatus (belonging to Scorpididae) with large eye was adopted as the material. The fish was trained to select one of either a vertically or horizontally striped pattern on the simultaneous presentation of these two figures in water (Fig. 3). This fish showed a keener sight than the Erlitze, as the former has larger eyes than the latter so much, so that the eye axis length of the former is 8 mm, while that of the latter is 2 mm (BRUNNER, 1934, p. 313).

This study was undertaken during the warm seasons of 1936 and 1937 at the Seto Marine Biological Laboratory of Kyoto University. The preliminary report on the subject has been published in

The visual acuity of fish (in Japanese). Zool. Mag., vol. 48, p. 203, 1936.

Fig. 1. *Microcanthus strigatus.* Scale in cm. ×1

II. Method

The fish used for experiment was the coral fish *Microcanthus strigatus* (CUVIER et VALENCIENNES), in Japanese called "Kagokakidai." The fish has a body length of about 20 cm in full growth, and has seven dark colored striations along the body axis on a lemon yellow background (Fig. 1). Fish having a body length of from 9 to 11 cm were chosen for the experiment.

Each fish was kept alone in a wooden aquarium of the size 72.5 cm (length), 27.3 cm (width) and 24 cm (depth). The water level was kept 16.5 cm from the bottom (Fig. 2). On one end of the aquarium two rectanglar figures of 2.5×2.5 cm were simultaneously presented in sea water, each separated 5 cm apart by black painted wooden board (Fig. 3A). Behind the figure a small piece of cooked lobster

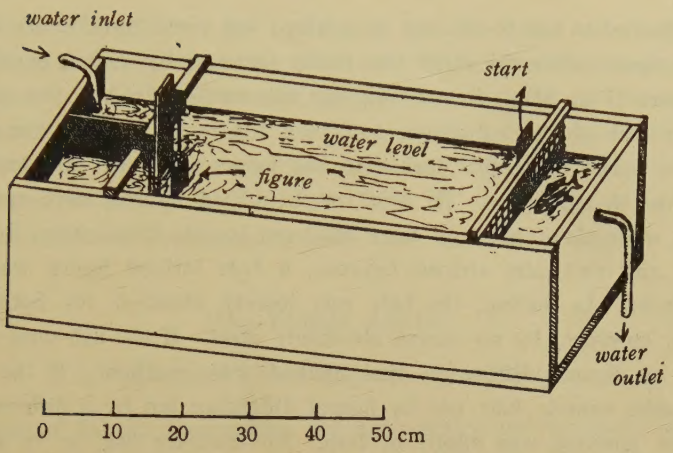


Fig. 2. The aquarium used for experiment.

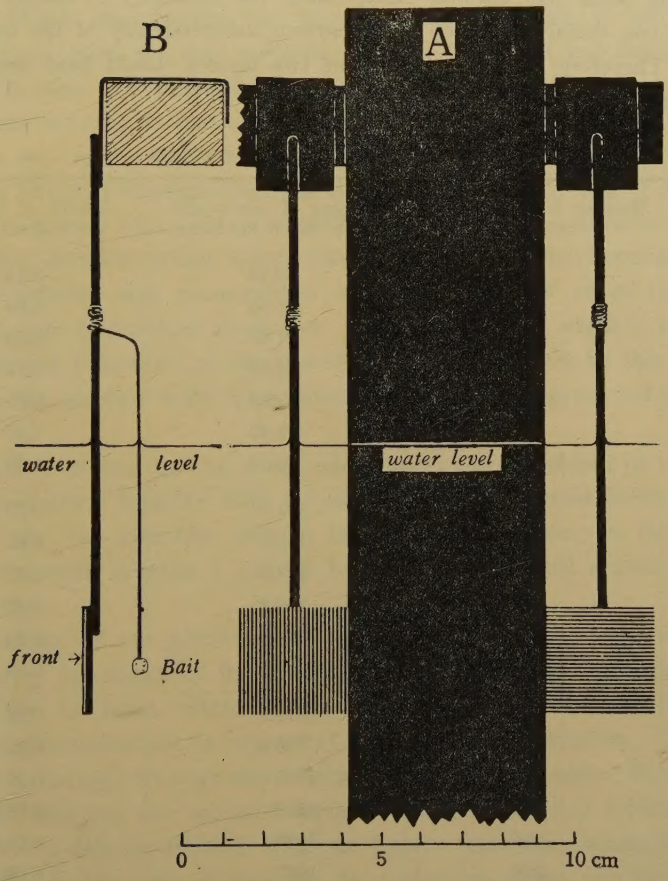


Fig. 3. Arrangement of positive and negative figures. A is the frontal view, and B the side view.

meat was attached as bait to the end of a wire; one piece was loosely attached behind the positive figure while the other was firmly fastened by melted paraffine behind the negative figure (Fig. 3B). In training, the fish was confined in the starting chamber at the other end of the aquarium, and then the metal plate on the entrance of the chamber was raised. The fish dashed to the figure and tried to obtain the bait on the back side of the figure. At first rough striped figures were used as training figures, and when these patterns were mastered in selecting correct figure (one of the horizontally and vertically striped figures), a finer striped figure was presented for further training. In testing, the bait was loosely attached for both figures. This method was, however, by no means absolutely good. If the fish once had learned to select bait by figural difference, this method was excellent. If the fish had once learned to take eatable bait not by figural difference but by a difference in the bait itself, further training was totally in vain. An unclever fish, so to speak, deceived by the experimental mechanism, yielded desirable results for the experimenter. In the course of training some fish showed occasionally the tendency to select the figure repeatedly from one definite side of the aquarium independently of the difference of figural pattern. Therefore the position of the two figures should have been changed at random in each trial of training or in the test.

Table 1. Width of black and white stripes.

No. of figure	Number of black lines in 25 mm	Number of black and white lines in 10 cm	Width of black or white lines in mm
1	1	10.94	9.14
2	2	18.08	5.53
3	4	27.88	3.59
4	5	36.62	2.73
5	7	51.28	1.95
6	10	71.43	1.40
7	13	95.50	1.05
8	19	137.9	0.73
9	22	160.0	0.63
10	27	172.2	0.52
11	33	239.8	0.42
12	40	298.5	0.34
13	57	420.0	0.24
14	82	611.1	0.16
15	107	789.0	0.13
16	135	1000	0.10
17	165	1209	0.083
18	196	1429	0.077
19	228	1667	0.060
20	270	1964	0.051

Preparation of the figures. 263 equidistant parallel lines were engraved with a diamond pencil on a rectanglar bronze plate (9.3×9.3 cm) ; and this bronze grating was printed on paper. The printed striped pattern was reduced by photograph to the desirable magnitudes. The figures of 2.5×2.5 cm used in this experiment were made from the printing of the negatives thus prepared (Figs. 14—20 in Table 1). The figures of rougher stripes (Figs. 1—13 in Table 1) were prepared by photography from carefully handdrawn equidistant parallel lines on drawing paper.

III. Visual Acuity

a. Minimal physiological visual angle

The training of fish to discriminate the horizontally and vertically striped figures was started at first with relatively roughly striped figures. In many cases it was began with the figure No. 9 described in Table 1 (width of black or white stripe 0.4 mm). When the training was proved to be completed by test, further training was continued with the finer patterns (No. 12, 14, 16, 18 and finally 20). When the finer figures were first presented, the fish could not discriminate them at first. Further training was required to master the new condition.

Under day light or under bright incandescent illumination, the limit of the fineness of parallel striation discriminated by the fish lay between figures No. 18 and No. 20 (width of black or white striation 0.077 mm and 0.051 mm respectively).

Relation between visual acuity and illumination. The experiment to determine the above relation was accomplished under conditions of varied illumination. From 0.1 to 423 Lux illuminated conditions were prepared by electric lamp arrangement. The upper and four sides of the aquarium were surrounded by thin and opaque paper to diffuse the electric light from above. The result is presented in Table 2 and in Fig. 4.

The curve plotted in Fig. 4 indicates clearly the role played by the cones in vision under illumination brighter than 5 Lux. Under illumination below 0.4 Lux the rods seems to play the principal part in figural discrimination. In the transitory phase under illumination between 5 and 0.4 Lux, the vision would depend on both the cones and the rods.

Calculation of the physiological visual angle based on experiment. The visual angle may be calculated by the minimal width of striation discriminated and the eye distance from the figure when the fish has seen the object distinctly. Of course the distance of discrimination is dependent on the width of striation. The coarse pattern may be discriminated at a greater distance than the finer ones. However, it is a well known fact that fish are normally myopic. As Tables 3 and 4 indicate, the fish sees the object at a definite distance from the figures relatively independent of the width of striation. At the point of apparent discrimination of the two figures, the course of swimming turned to one of the two figures. The distance of this turning point of

Table 2. Minimum width (d) of parallel stripes discriminated by four fish (No. 6, 1, 2, 4) under different illuminations.

Illumination I in Lux	log I	Width (d) of stripe in mm				Mean d in mm	$1/d$	Visual angle $d/40$ mm
		No. 6	No. 1	No. 2	No. 4			
423	2.63	0.051	0.051	0.051	0.077	0.058	17.4	4′59″
282	2.46	0.051	0.051	0.051	0.077	0.058	17.4	4′59″
104	2.02	0.083	0.083	0.077	0.100	0.086	11.6	7′25″
39.6	1.60	0.164	0.127	0.164	0.237	0.146	6.85	12′43″
11.0	1.04	0.237	0.164	0.164	0.237	0.201	4.98	17′
5.0	0.70	0.237	0.237	0.237	0.237	0.237	4.22	20′
2.2	0.34	0.237	0.237	0.237	0.237	0.237	4.22	20′
0.4	−0.40	0.237	0.237	0.237	0.237	0.237	4.22	20′
0.3	−0.52	0.335	0.335	0.335	0.335	0.335	2.99	30′
0.1	−1.00	0.417	0.417	0.417	0.417	0.417	2.39	36′

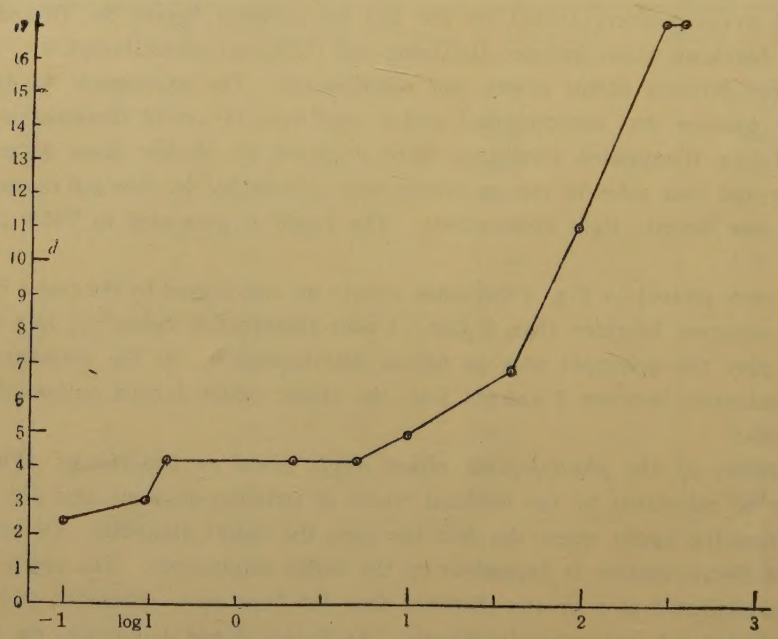


Fig. 4. The relation between visual acuity ($1/d$) and illumination. Plotted from the data in Table 2.

Table 3. The number of cases in which the fish apparently discrimitated the simultaneously presented figures at different distances. Under illumination lower than 11 Lux.

Distance from figure in cm	No. of figure and the width of striation in mm										Sum
	No. 11 0.42 mm	No. 12 0.34	No. 13 0.24	No. 14 0.16	No. 15 0.13	No. 16 0.10	No. 17 0.08	No. 18 0.07	No. 19 0.06	No. 20 0.05	
1	—	—	—	—	—	—	—	—	—	—	0
2	1	—	—	—	—	1	—	—	—	1	3
3	4.5	1	2	—	—	1	5	4	—	1	18.5
4	9.5	3	7	1	1	—	8	13	3	8	53.5
5	6	2	9	1	—	1	4	5	5	11	44
6	1	1	15	1	4	7	8	5	2	7	51
7	1	—	1	—	1	—	—	3	—	1	7
8	—	1	—	1	2	3	3	3	—	3	16
9	—	—	—	—	—	2	—	4	—	1	7
10	—	—	—	3	3	2	—	8	—	1	17
11	—	—	—	—	1	—	1	—	—	1	3
Mean distadce in cm	4.3	4.9	5.2	7.6	7.7	6.7	5.2	6.2	4.9	5.6	

Table 4. The number of cases in which the fish apparently discriminated the simultaneously presented figures at different distances.

Distance from figure in cm	Under illumination lower than 11 Lux	Under illumination higher than 100 Lux	Total sum
1	—	—	0
2	3	1	4
3	18.5	23	41.5
4	53.5	116	169.5
5	44	94	138
6	51	77.5	128.5
7	7	67	74
8	16	31.5	47.5
9	7	53	60
10	17		
11	3	100	120
12	—		
14–16	—	38	38
18–20	—	22	22
25	—	21	21
30	—	18	18
35	—	3	3
40	—	9	9
Sum	220	674	894

swimming course and the distance of to and fro swimming plane before the figures indicated the distance of distinct discrimination of the two figures. There were several cases in which the fish discriminated the coarse striped pattern at a distance of 40 cm, but these were rather exceptional. In most cases the discrimination was made at 4 cm from the figures as Tables 3, 4 and Fig. 5 indicate. The visual angle (ω) is calculated by $\omega = \frac{\text{minimal width of striation}}{\text{distance of distinct discrimination}}$. As indicated in Table 2, fish No. 6, 1 and 2 discriminated figure No. 20 (width of single stripe 0.051 mm), then

$$\omega = 0.051 \text{ mm}/40 \text{ mm} = 0.001275 = 4'23'' \quad \cdots\cdots (1)$$

The average width of striation discriminated by four fish in Table 2 was 0.058 mm then

$$\omega = 0.058 \text{ mm}/40 \text{ mm} = 0.00145 = 4'59'' \quad \cdots\cdots (2)$$

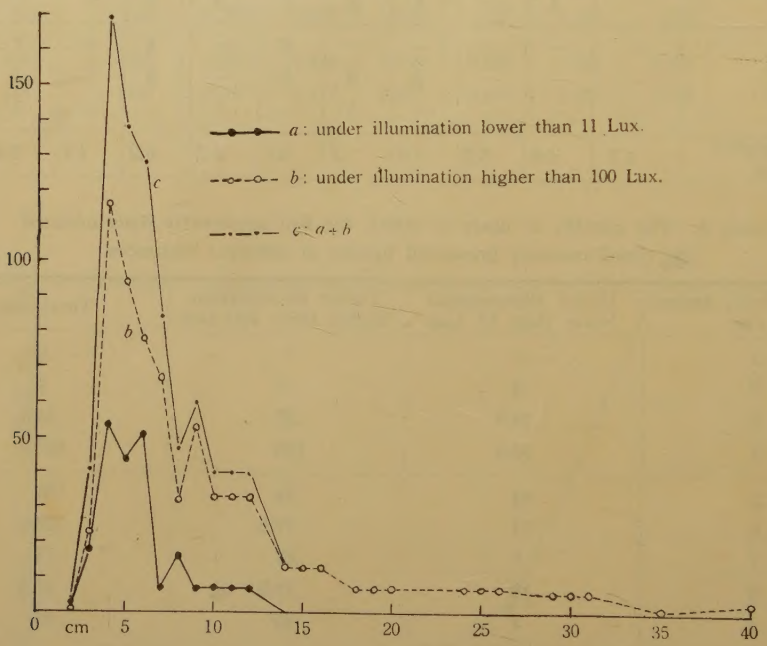


Fig. 5. The frequency of cases in which the fish apparently discriminated the two figures.

b. Minimal morphological visual angle

The morphological visual angle may be gotten by knowing the mean cone distance in the retina, the refraction index of the sea water and the total refraction index of the lens.

1) *Mean distance of cones in the retina.* The cones are distributed regularly in the retina, but they are not equidistant. As the direct measurement of their distances

from each other in microscopic preparation was extremely difficult, it was assumed that the cones were arranged equidistant to each other, or that they were distributed in the center of minute regular hexagon. If a is the side of the regular hexagon, its area is

$$3\sqrt{3}/2-a^2 \qquad \cdots\cdots(3)$$

If d is the distance of the two centers of the adjacent hexagon, the distance (d) of each cone is

$$d=\sqrt{3}\,a \qquad \cdots\cdots(4)$$

In the microscopic preparation of the retina dissected parallel to the retinal surface, the number of cones was counted in the rectanglar area of $93\times93\mu$. The area of one cone in the area of $\overline{93\mu}^2$ containing n cones was ($m=93\mu$)

$$\frac{m^2}{n}=\frac{3\sqrt{3}}{2}a^2 \quad \text{or} \quad a=\sqrt{\frac{2}{3\sqrt{3}}}\cdot\frac{m}{\sqrt{n}} \qquad \cdots\cdots(5)$$

From (4) and (5)

$$d=\sqrt{3}\,a=\sqrt{\frac{2}{\sqrt{3}}}\cdot\frac{m}{\sqrt{n}}=\frac{93}{\sqrt{n}}\cdot\sqrt{\frac{2}{\sqrt{3}}} \quad \text{or} \quad d=\frac{99.93}{\sqrt{n}}\mu \qquad \cdots\cdots(6)$$

From this relation, if the number n of cones in $\overline{93\mu}^2$ is known, the mean distance of cones in the retina can be estimated. If $n=140$ (Table 7)

$$d=99.93/\sqrt{140}=8.4\mu \qquad \cdots\cdots(7)$$

2) *Calculation of the total lens refraction index* (n_2). MATTHIESSEN (1886) gave the value of n_2 as 1.6763 in codfish and 1.6476 in carp. The precise value of n_2 should be measured for each species of fish. In determining the total lens refraction index of *Microcanthus strigatus*, the following relation for the spherical lens system is expected (HOUSTOUN 1924, p. 44):

F: focal distance of lens
r: radius of lens
n_1: refraction index of the sea water (1.339)
n_2: total refraction index of lens (unknown)
m: length of eye axis ($F+r$)

$$F+r=r\cdot\frac{n_2}{2(n_2-n_1)}+r=r\cdot\frac{3n_2-2.678}{2(n_2-1.339)}$$

$$r\cdot\frac{3n_2-2.678}{2(n_2-1.339)}=m, \quad \text{or} \quad n_2=\frac{2.678(m-r)}{2m-3r} \qquad \cdots\cdots(8)$$

From the direct measurement of r and m as indicated in Table 5, $m-r/2m-3r$ was calculated for fish 3—17 cm long. This value was practically constant (0.623). From (8)

$$n_2=\frac{2.678(m-r)}{2m-3r}=2.678\times0.623=1.668 \qquad \cdots\cdots(9)$$

Table 5. Calculation of the total refraction index (n_2) of the fish eye from the radius of lens (r) and the axis of the eye (m); $n_2=\frac{2.678(m-r)}{2m-3r}=2.678\times0.623=1.668$.

Body length in cm	Mean length of the radius of lens (r) in mm	No. of specimen	Mean length of the axis of eye (m) in mm	No. of specimen	$m-r$ in mm	$2m-3r$ in mm	$\frac{m-r}{2m-3r}$
4– 5	1.18	2	4.07	2	2.89	4.60	0.627
5– 6	1.22	6	4.35	6	3.13	5.04	0.620
6– 7	1.36	7	4.67	5	3.31	5.26	0.629
7– 8	1.52	1	5.50	1	3.98	6.44	0.620
8– 9	—	—	—	—	—	—	—
9–10	2.09	7	7.60	3	5.54	8.93	0.620
10–11	2.26	7	7.95	1	5.69	9.12	0.640
11–12	2.49	2	—	—	—	—	—
12–13	2.52	2	9.13	2	6.61	10.70	0.618
13–14	2.70	5	—	—	—	—	—
14–15	3.23	1	—	—	—	—	—
15–16	3.34	1	11.80	1	8.46	13.58	0.623
16–17	3.55	3	12.10	1	8.55	13.55	0.631
						Mean	0.623

3) *Relation of minimal physiological and morphological visual angle.*

ω: minimal visual angle measured by experiment (0.001275 or 4′ 23″)

ω': morphological visual angle

n_1: refraction index of the sea water (1.339)

n_2: total refraction index of lens (1.668)

then $\omega'=\frac{n_1}{n_2}\omega=\frac{1.339}{1.668}\omega=0.80\,\omega$ From (1) $\omega=\frac{0.051\text{ mm}}{40\text{ mm}}=0.001275$ or 4′ 23″ then

$$\omega'=0.80\,\omega=0.80\times0.001275=0.00102 \quad \text{or} \quad 3'\ 30'' \quad \cdots\cdots\cdots(10)$$

From Fig. 6, $h=bt g\omega'=b\omega'$, $(tg\omega'=\omega')$

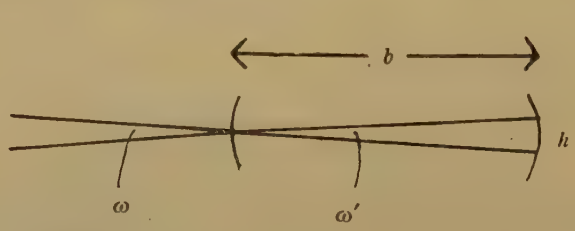


Fig. 6. The schema of the optical system of the eye.

For fish with body lengths of from 10—11 cm, the length of eye axis was from 7.60 to 8.40 mm, or 8 mm in average value by direct measurement.

From (10) $h = b\omega' = 8.00 \times 0.00102 \text{ mm} = 8.2\mu$ ·····(11)

4) *Calculation of morphological visual angle from the mean cones distance.* From Table 7 the mean number of cones (n) contained in $93\mu^2$ area in the central and back parts of the retina of fish with body lengths of 10—10.8 cm was 140. The mean distance of cones is given as already mentioned in (6).

$$d = \frac{99.93}{\sqrt{n}}\mu = \frac{99.93}{\sqrt{140}}\mu = 8.4\,\mu$$

The value of d based on experimental data was 8.2μ (11) and the value calculated from the mean cone distance was 8.4μ as above mentioned. Both values practically coincide, allowing the high probable error in experiment and measurement in this type of work.

The minimal morphological visual angle may also be calculated by the length of eye axis and the mean distance of cones as follows:

$$\omega' = 8.4\mu/8 \text{ mm} = 0.00105 \quad \text{or} \quad 3'\ 36'' \text{ ·····(12)}$$

3′ 36″ is not a very different value from the 3′ 30″ theoretically deduced from minimal physiological visual angle (10).

IV. Distribution of Cones in the Retina

Fish retina was fixed in an alcohol-formalin mixture (2 parts 80% alcohol plus 1 part 40% formaldehyde after PETERFI), and the fixed retina was dissected by microtome after paraffine imbedding. Section was made parallel to the retinal surface. 9 parts of the retina were chosen for dissection as indicated in Fig. 7. Microtomic sections

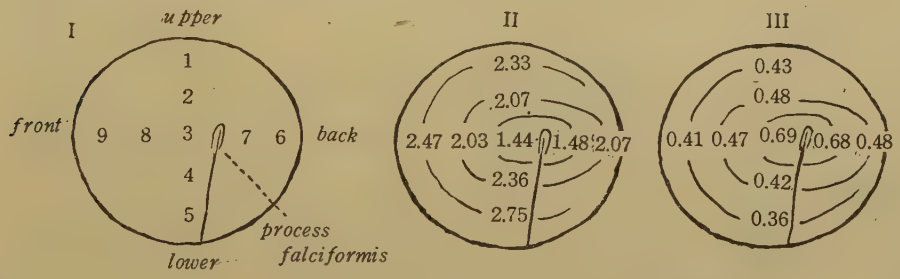


Fig. 7. The retina of *Microcanthus strigatus* enlarged.
I. 9 parts of the retina dissected.
II. The ratio of the number of cones/ganglion cells as indicated in Table 10.
III. Reciprocal of the above as in Table 10.

were stained by HEIDENHEIN's hematoxylin and eosin. The cones were stained pink red, and the ganglion cells blue violet. The number of cones and ganglion cells were counted in an area $93 \times 93\mu$. In Table 6 is presented the number of cones in 9 parts of the retina of this fish with body lengths from 9.4 to 16.5 cm.

Table 6. The number and the mean distance of cones in the area of $\overline{93\mu}^2$ in the different sections of retina.

Specimen	Body length in cm	Part of the retina									Mean number	Mean distance in μ
		1	2	3	4	5	6	7	8	9		
C	9.4	76	93	156.6	90.5	100	141.5	171.5	80	114	113.5	9.4
b	10	61	80.5	134.5	87.5	96	136	175	121	91	109.2	9.6
i	10.3	66	67	120.5	81	80	141.5	100	99	94	94.3	10.3
B	10.4	58	79.5	163	77	72.5	182.5	157.5	86	87.5	85.9	10.2
d	10.4	64	74.5	137	85	96.5	147	162	101	124	110.1	9.5
k	10.8	70.8	62	102	83.5	79	128	128	85	81	91	10.5
W	10.8	67.5	54	107	73	73.5	119.5	100.5	102.5	84.5	86.9	10.7
Mean number of cones		66.2	72.9	131.5	82.5	85.4	142.3	142.1	96.4	96.6	100.1	
Mean distance of cones calculated from $\frac{99.93}{\sqrt{n}}$ in μ		12.2	11.7	8.7	11.0	10.8	8.4	8.4	10.2	10.2		10.0

Specimen	Body length	1	2	3	4	5	6	7	8	9	Mean number	Mean distance
3	12.3	50.5	54.5	136.5	60.5	62.5	82.5	88	68.5	63	74.1	11.6
4	13.0	45	52	102.5	64	51	86.5	122	83.5	69	75.1	11.5
n	13.6	46.8	57	79.5	53.3	59	110.3	106	75.5	80.5	74.3	11.6
m	13.9	43.5	42.5	95	49	74	83	89.5	82.5	63	69.1	12.0
Mean number of cones		46.5	51.5	103.4	56.7	61.6	90.6	101.4	77.6	68.9	73.2	
Mean distance of cones in μ		14.7	13.9	9.8	13.3	12.7	10.5	9.9	11.3	12.0		11.7

Specimen	Body length	1	2	3	4	5	6	7	8	9	Mean number	Mean distance
21	15.3	—	37	71.5	44.5	—	54	68	64.5	38	53.9	13.5
22	16.5	32	41.5	65	32.5	29	53	54	66	76.5	49.9	14.3
25	16.5	23	24	66.5	30.5	33	61.5	66.5	44.5	38	43.1	15.2
Mean number of cones		27.5	34.2	67.7	32.5	31	56.2	62.8	58.3	50.8	49.3	
Mean distance of cones in μ		19.1	17.1	12.1	17.5	18.0	13.3	12.6	13.1	14.0		14.3

The cones are distributed more densely in the center or bottom of the eye (Table 6) and in the outer or back part of the retina than the other parts. Hence they are smaller in size than the other parts. With the growth of fish the cones in a definite area of the retina decrease in number and increase in size. The mean distance of cones in the whole retina vary from 10.0μ, 11.7μ and 14.3μ correspondingly with the size of fishes 9.4—10.8 cm, 12.3—13.9 cm and 15.3—16.5 cm.

In Table 7 is shown the density and the mean distance of cones in the central

Table 7. The number and mean distance of cones in $\overline{93\mu}^2$ in the central (3) and back (outer 6, 7) part of retina.

Specimen	Body length in cm	Part of retina			Mean
		3	6	7	
a	10	168.5	141.5	154	154.5
b	10	109	173.5	175	152.5
c	10	135	151	108	131.3
i	10.3	120.5	141	100	120.5
h	10.3	128	186.5	151	158.5
d	10.4	137	147.5	162	148.8
f	10.4	150.5	127.5	135	137.7
B	10.4	163	182.5	157.5	167.7
k	10.8	102	128.5	128	119.3
l	10.8	107	119.5	105	110.5
Mean number of cones		132	150	138	140
Mean distance of cones in μ calculated from $d=99.93/\sqrt{n}$		8.7	8.2	8.5	8.4

and the back part of the retina where the density of cones was highest (3, 6, 7 in Fig. 7 I) of such size of fish as used in the experiment (10—11 cm long). In these parts of the retina there existed 140 (n) cones in $\overline{93\mu}^2$ area and mean distance of them was 8.4μ. In Tables 8, 9 and 10 the relation between the density of the cones and the ganglion cells directly connected with the cones is shown as the result of measurement of the dissected materials. This relation is shown in Fig. 7 II, III. In the central (3) and the rear adjacent region (7), the number of cones per 1 ganglion cells is minimal (II in Fig. 7) or the number of ganglion cell per 1 cone is maximal (III in Fig. 7).

Table 8. Number of cones in $\overline{93\mu}^2$ area in different parts of the retina.

Specimen	Body length in cm	Part of retina								
		1	2	3	4	5	6	7	8	9
C	9.4	76	93.5	156.5	90.5	100	141.5	171.5	80	114
N	10	61	80.5	134.5	87.5	96	136	175	121	91
Q	10.3	74.5	63.5	121.5	80.5	80	109.5	92.5	82.5	85
R	10.3	57	70.5	119.5	81.5	80.5	173.5	108	115.5	102.5
B	10.4	58	79.5	163	77	72.5	182.5	157.5	86	87.5
P	10.4	64	67	130.5	78	87	154.5	165	115	135.5
A	10.8	58	55	85	80.5	82	141.5	133	86	86
G	10.8	83.5	68.5	119	86.5	75.5	115	123.5	84.5	76.5
W	10.8	67.5	54	107	73	73.5	119.5	100.5	102.5	84.5
J	12.5	50.5	54.5	136.5	60.5	62.5	82.5	88	68.5	63
I	13	45	52	102.5	64	51	86.5	122	83.5	69

Table 9. Number of ganglion cells in $\overline{93\mu}^2$ area in different parts of the retina.

Specimen	Body length in cm	Part of retina								
		1	2	3	4	5	6	7	8	9
C	9.4	33	46.8	94	35	39.4	75.6	135	41.1	47.3
N	10	31	34	94	30	36	65.9	94	70.5	47.3
Q	10.3	30.2	33	85	36.8	26	52	49.5	40.5	33
R	10.3	27	36	101.7	49.5	24.3	70.5	88.5	54	42.3
B	10.4	24.1	23.5	117.5	31.5	25.5	91.3	104.7	45.3	35.4
P	10.4	—	—	103	28.8	28	70	126	65	56.3
A	10.8	31	27	70.2	28	33	78.8	98	45	30.2
G	10.8	30.8	30.8	77.3	50.6	29.4	49.9	81	36.1	37.8
W	10.8	25.5	31.5	63	34	25.1	57	69.8	45	32
J	12.5	21.7	24.6	96	27.5	27	44.4	54.3	29.2	29.5
I	13	22	23	64	25	23	42	90	43.5	22

Table 10. Ratio of the number of cones/ganglion cells in different parts of the retina.

Specimen	Body length in cm	Part of retina								
		1	2	3	4	5	6	7	8	9
C	9.4	2.30	1.56	1.66	2.59	2.54	1.87	1.26	1.94	2.61
N	10	1.97	2.37	1.43	2.91	2.67	2.06	1.86	1.72	1.92
Q	10.3	2.47	1.91	1.43	2.18	3.08	2.10	1.87	2.04	2.55
R	10.3	2.11	1.96	1.17	1.65	3.30	2.06	1.22	2.14	2.42
B	10.4	1.78	2.41	1.39	2.44	2.84	2.01	1.50	1.90	2.47
P	10.4	—	—	1.26	2.71	3.10	2.21	1.31	1.77	2.41
A	10.8	1.87	2.04	1.21	2.87	2.71	1.81	1.36	1.91	2.85
G	10.8	3.75	2.23	1.54	1.73	2.57	2.30	1.52	2.34	2.03
W	10.8	2.65	1.71	1.70	2.15	2.93	2.07	1.44	2.28	2.64
J	12.5	2.33	2.22	1.42	2.20	2.31	1.86	1.62	2.34	2.14
I	13	2.05	2.26	1.60	2.56	2.22	2.06	1.35	1.92	3.14
Mean		2.33	2.07	1.44	2.36	2.75	2.07	1.48	2.03	2.47
Reciprocal of the mean		0.43	0.48	0.69	0.42	0.36	0.48	0.68	0.49	0.41

Although there is morphologically no clear Fovea in this fish, there is a region of relatively broad extension where the image of external object should be formed most accurately compared with the other regions of the retina as shown in II, III of Fig. 7. It is an interesting fact that such an accurately seeing region should be located in the central and rear adjacent region of the retina. The minute structure of the retina is so constructed that the fish is able to see accurately the front part of the head.

V. Change of Visual Acuity with Age

The resolving power of the eye increases with the growth of lens and decreases with the enlargement of adjacent cones distance. A smaller fish has a small eye i.e. small lens, but it has small condensed cones. With the growth of fish the lens increase in diameter but the cone in the retina becomes larger and hence the distance of each cone is enlarged. The change of the visual acuity of fish with age can be tested experimentally, but in this report this point has been made clear morphologically by the measurement of lens diameter and the mean distance of cones (Table 11).

Table 11. Relative visual acuity (S) of the fish calculated from the radius of lens and from the mean distance of cones. The number in bracket denotes the number of specimen.

Body length in cm	Mean radius of lens r in mm	$F=2.54r$* in mm	$F+r=3.54r$ in mm	Mean number of cones in $\overline{93\mu}^2$	Mean distance of cones $d=\frac{99.93}{\sqrt{n}}\mu$	$1/d$	Relative visual acuity $S=\frac{1}{\omega'}=\frac{F+r}{d}$
4– 5	1.18 (2)	3.00	4.18	190 (3)	7.25	0.138	0.58
5– 6	1.22 (6)	3.10	4.32	180 (6)	7.35	0.136	0.60
6– 7	1.36 (7)	3.45	4.81	179 (7)	7.46	0.134	0.65
7– 8	1.52 (1)	3.86	5.38	168.5 (2)	7.69	0.130	0.70
8– 9	—	—	—	147.5 (2)	8.25	0.121	—
9–10	2.09 (7)	5.23	7.29	149 (4)	8.19	0.122	0.89
10–11	2.26 (7)	5.74	8.00	137 (7)	8.54	0.117	0.94
11–12	2.49 (2)	6.32	8.81	115 (1)	9.34	0.107	0.94
12–13	2.52 (2)	6.40	8.92	103 (2)	9.89	0.101	0.94
13–14	2.70 (5)	6.86	9.56	94.5 (2)	10.3	0.097	0.93
14–15	3.23 (1)	8.20	11.43	—	—	—	—
15–16	3.34 (1)	8.39	11.73	62.5 (2)	12.6	0.079	0.93
16–17	3.55 (3)	9.02	12.57	61 (2)	12.8	0.078	0.98

* For spherical lens $F=\frac{n_2 r}{2(n_2-n_1)}$, $n_1=1.339$, $n_2=1.668$; then $F=2.54r$.

Morphological visual angle (ω') is given by the formula $\omega'=\frac{\text{mean distance of cones}}{\text{length of the eye axis}}=\frac{d}{F+r}$ The relative visual acuity (S) of the eye is given as $S=1/\omega'=(F+r)/d$, and is calculated in Table 11. The mean distance of cones was measured in the regions 3, 6 and 7 as in Fig. 7 I, where the density of cones was greatest. The lens diameter was directly measured from fresh material. The eye axis was calculated by r, as $F+r=2.54r+r=3.54r$. For spherical lens $F=n_2r/2(n_2-n_1)$, $n_1=1.339$ (for sea water) and $n_2=1.668$ (from Table 5); then $F=1.668r/2(1.668-1.339)=1.668r/0.658=2.54r$. As shown in Fig. 8, the visual acuity of this fish increases with age becoming practically constant when the length of the fish reaches 10 cm so that the fish in maturity obtains a more accurate image of outer world than the young immature ones.

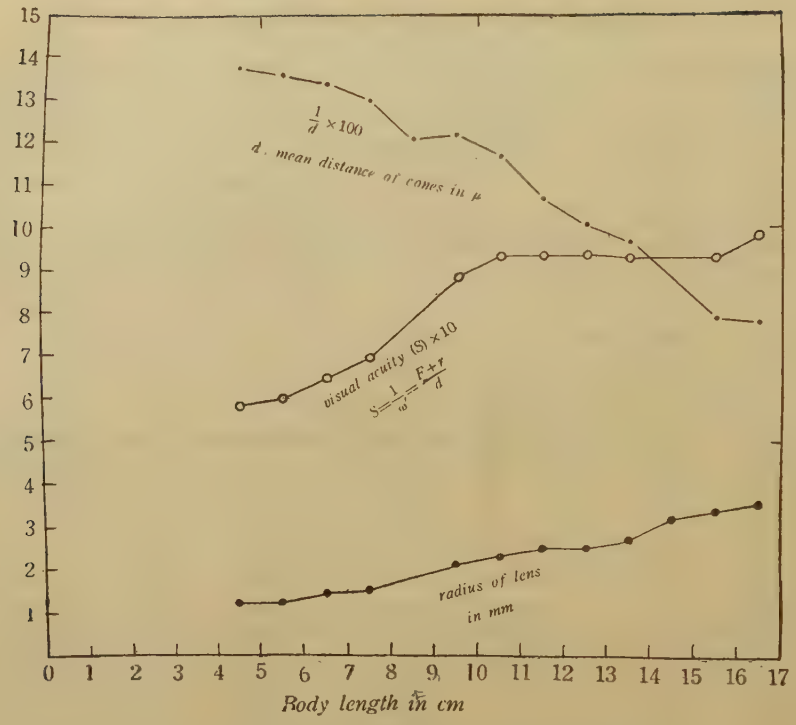


Fig. 8. Change of visual acuity with age.
— • — • — reciprocal of the mean cone distance.
— ● — ● — radius of lens.
— ○ — ○ — relative visual acuity (S).

VI. Figural Transposition

a) *When unexperienced equally striped figures presented.*

After the fish had been trained to the choice of a vertically striped figure of No. 12 (width of black or white line 0.34 mm) as against a horizontally striped figure, figure set No. 1 (width of each stripe 3.6 mm) was presented and the fish took bait from the vertically striped figure in spite of the coarser pattern.

b) *When unequally striped figures presented.*

The fish had been trained to choose the horizontally striped figure No. 12 (width of stripe 0.34 mm). After this training, both the horizontally striped figure No. 1 (width of stripe 3.6 mm) and vertically striped figure No. 12 (width of stripe 0.34 mm) were presented for free choice. The fish chose the rougher striped horizontally striped figure. After this test the relation of the above both figures was reversed (that is, horizontally striped figure No. 12 and vertically striped figure No. 1 were presented). The fish chose the originally trained horizontally striped No. 12 figure. Further tests

of the same kind and in other figural combinations were carried out with principally the same results. It is clear that, in addition to accurately seeing the striation, the fish were able to distinguish the vertical and horizontal relation of the figural pattern.

c) *Absolute and relative selection.*

Three sorts of vertically striped rectangular figures 7×7 cm were prepared (Fig. 9). Five fish had been trained to choose the finer stripe II (+) against the rougher I (−). After training, figures II and III were presented for free choice. Next the same group

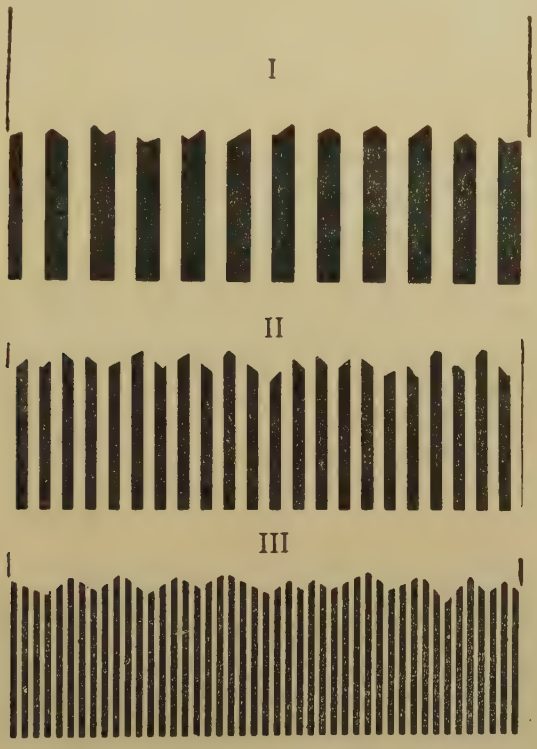


Fig. 9. Lower part of three vertically striped figures (7×7 cm).

of fish were trained with figures II (+) and III (−). As a test figures I and II were presented.

The two figures were hung in sea water closely side by side. The same eatable bait was attached to the ends of wires hung just in front of the figural centers. At the outer side of each figure, a movable wooden plate was prepared, and when the fish had dashed to the negative or prohibited figure, the wooden plate was suddenly slid by experimeter's hand before the prohibited figure to discourage the fish taking the bait from the negative figure. When the fish took the bait before the positive figure nothing was done.

Such training was continued from 200 to 400 times over a period of 20 days. At intervals tests were made with a new pair of figures leaving the fish to free choice of the figure.

Table 12. Trained with the figures I (−) and II (+). Test was made with figures II and III. The number indicates the case of relative selection in 10 tests, that is, 10 indicates 10 choices of III, and 0 indicates no choice of III, or 10 choices of II. 5 indicates 5 choices of III in 10 tests.

No. of fish	Number of III selection in test within the trained number of cases			
	Within 100 training	200	300	400
A	8	10, 8	—	—
B	2	1	5, 3	—
1	5	2	4, 7	5
2	4	5	—	—
3	4	3	0	2

Table 13. Trained with figures II (+) and III (−). Test was made with figures I and II. The number indicates the case of relative selection in 10 tests. 7 indicates the selection of I seven times in 10 tests.

No. of fish	Number of I selection in test within the trained number of cases			
	Within 100 trainings	200	300	400
A	—	3, 2	5, 0	5
B	9	5, 5	6, 5	—
1	7	5	5	5
2	—	7	5	6, 6
3	7	6	6, 5	—

Table 14. Arranged from the Tables 12 and 13. Evaluation of the selection numbers given in the above two tables. 0—3 absolute selection (*a*), 4—6 absolute and relative selection (*a*, *r*), 7—10 relative selection (*r*).

	No. of fish	Within 100 trainings	200	300	400
From the Table 12	A	*r*	*r*	—	—
	B	*a*	*a*	*a*, *r*	—
	1	*a*, *r*	*a*	*a*, *r*	*a*, *r*
	2	*a*, *r*	*a*, *r*	—	—
	3	*a*, *r*	*a*	*a*	*a*
From the Table 13	A	—	*a*	*a*	*a*, *r*
	B	*r*	*a*, *r*	*a*, *r*	—
	1	*r*	*a*, *r*	*a*, *r*	*a*, *r*
	2	—	*r*	*a*, *r*	*a*, *r*
	5	*r*	*a*, *r*	*a*, *r*	—

(continued)

relative	4 (50%)	2 (20%)	—	—
absolute, relative	3 (37.5%)	4 (40%)	6 (75%)	4 (80%)
absolute	1 (12.5%)	4 (40%)	2 (25%)	1 (20%)
Total cases	8 (100%)	10 (100%)	8 (100%)	5 (100%)
* Relative percentage	69%	40%	37.5%	40%
* Absolute percentage	31%	60%	62.5%	60%

* The percentage of absolute and relative cases (a, r) was divided by 2, and each numerical value was added to either the absolute cases or the relative cases.

Although the individual difference was great and the fish seemed in some cases to choose the figure by temperament, the general tendency of relative selection at first and of absolute selection later on with the progress of further training can hardly be denied.

VII. Interpretation

When such a fish as *Microcanthus strigatus*, whose minimal visual angle is 4′23″, approaches a fishing line of 0.08 mm in diameter, the drail would be just found by fish at the distance of 6.3 cm if the drail is dark colored and non-transparent. If the fish has just found the drail at x cm from it, x can be calculated as follows:

0.08 mm/x cm = tg 4′23″ = 0.001275, then x = 0.08 mm/0.001275 = 6.3 cm. The visual angle of the drail at 5 cm distance is 0.08 mm/5 mm = 0.0016 or 5′30″. The fish whose minimum separabile is 4′23″ can easily find such a drail at 5 cm. To make a fishing line invisible to fish sight, man has by traditional experience devised fine, colorless and transparent fishing lines. On the other hand easily visible thick threads or sticks are used for fish weir, traps and barrier so as to let fish swim to a definite direction or place.

When such a fish having lesser visual acuity than *M. strigatus* (minimum separab. 4′23″), for instance, *Phoxinus laevis* (minimum separab. 11′) approaches the finest drail of 0.08 mm in diameter, the fish would scarcely perceive the drail even if it were colored and non-transparent, for the reason as such that the minimal visual angle of 11′ is reached first at the distance of 2.5 cm from the drail and that at such a short distance no clear image of an object would be formed on the retina of fish.

The curve indicating the relation between visual acuity and light intensity in man is sigmoid-formed (Fig. 10 I, KÖNIG, 1897). That of *Microcanthus strigatus* is continuous double sigmoid-formed Fig. 4, Fig. 10 III). That of *Phoxinus laevis* shows a brick point at low light intensity with a steep curve directed downward from it (Fig. 10 II, BRUNNER 1934). The double sigmoid form of visual acuity curve plotted in Fig. 4 and Fig. 10 III represents without doubt the functional difference of rods and cones in night and day vision of fish, as already pointed out by FRISCH (1924).

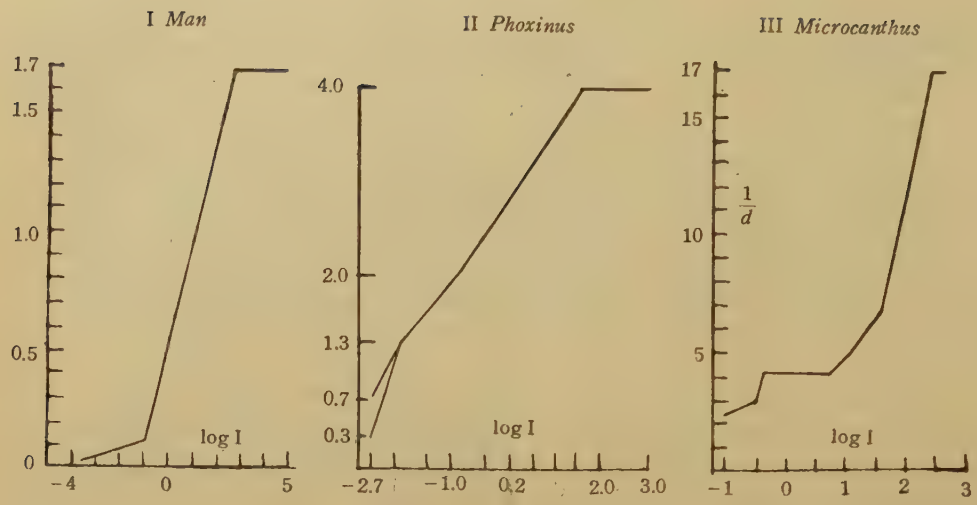


Fig. 10. Visual acuity curve under different illuminations. Ordinate—value of visual acuity, abscissa—log of Lux. I after KÖNIG 1897, II after BRUNNER 1934, III deformed from Fig. 4.

Table 15. The site of transition of the function between rods and cones.

Animal	Site of transition	Author
man	0.03 ...0.1 Lux	KÖNIG 1897
„	0.1.....1 Photon	HECHT et WOLF (after BUDDENBROCK 1952)
Rana temporaria	about 2 Lux	BIRUKOW 1937
sword-tail	0.1.....1 Milliambert	CROZIER et WOLF 1938
Phoxinus laevis	0.002...0.008 Lux	BRUNNER 1934
Microcanthus strigatus	0.4.....5 Lux	in this work

Table 16. Minimal morphological and physiological visual angle of different animals.

Animal	Minimal morpholog. visual angle	Minimal physiolog. visual angle	Author
man	18.5–74″	23.3–64″	after BIRUKOW 1937
rat	—	30–57′	LASHLEY 1932
lizard (area)	3′06″	—	EHRENHARDT 1937
(periphery)	12′07″	11′28″	
pigeon	—	2.7–3.1′	HAMILTON 1933
game cock	—	3.1–4′	JOHNSON 1914
Rana temporaria	6′48″	6′53″	BIRUKOW 1937
Phoxinus laevis	11′	11′	BRUNNER 1934
Microcanthus strigatus	3′36″	4′23″–6′35″ average 4′59″	in this work
honey bee	1°	1°	HECHT et WOLF 1929
Drosophila	4°	4°	GRAVEL (after BIRUKOW 1937)
	4°	9.28°	HECHT et WALD 1934
hermit-crab	1.75–3°	4.2°	BRÖCKER 1935
Uca pugnax	2.05°	3.87°	CLARK 1935

Visual acuity increases in proportion to the size of eye, and is inversely proportional to the distance of each cone. Let Sm and Sp denote visual acuity of *Microcanthus* and *Phoxinus* respectively, and dm, dp the cone distance in μ, and Mm, Mp the length of eye axis respectively ($dp=6.25\mu$ BRUNNER 1934), then

$$\frac{Sm}{Sp}=\frac{Mm}{dm}\cdot\frac{dp}{Mp}=\frac{8\text{ mm}}{8.4\mu}\,\frac{6.25\mu}{2\text{ mm}}=2.93$$

When visual acuity is compared in term of minimal morphological visual angle ($\omega'm$, $\omega'p$), then

$$\frac{\omega'p}{\omega'm}=\frac{11'}{3'36''}=\frac{11'}{3.60'}=3.05$$

When minimal physiological visual angle is compared,

then
$$\frac{\omega p}{\omega m}=\frac{11'}{4'23''}=\frac{11'}{4.38'}=2.51$$

Minimal morphological visual angle should be theoretically smaller than the minimal physiological visual angle, as the incident light refracts strongly in the eye medium. Minimal morphological visual angle (11′) given by BRUNNER (1934) for *Phoxinus laevis* seems to be too high in comparison with minimum separabile (11′) from the above consideration. From (10) $\omega'=\frac{n_1}{n_2}\omega$, then when $n_1=1.333$ (for fresh water) and $n_2=1.668$ (from Table 5).

$$\omega'=\frac{1.333}{1.668}\cdot 11'=8.80',\quad \omega'p/\omega'm=8.80'/3.60'=2.44$$

This value does not seem to be very far from 2.51.

From these comparisons, *Microcanthus strigatus* seems to have a 2 or 3 times keener vision than *Phoxinus laevis* as the eye size of both fishes suggests (Mm/Mp =8 mm/2 mm). In short, the difference in visual acuity between the two species of fish has been reasonably explained from the physiological and morphological points of view.

The following numerical values were found in *Microcanthus strigatus* of 10—11 cm in size:

ω, minimal physiological visual angle 4′23″ ……(1)
ω_1', minimal morphological visual angle deduced from (1) 3′30″ ……(10)
ω_2', minimal morphological visual angle calculated from measurement 3′36″…(12)
d_1, mean distance of cones calculated from measurement 8.4μ……(7)
d_2, mean distance of cones calculated from experimental data 8.2μ ……(11)
m_1, length of the eye axis measured 7.6—8.4 mm in average 8.0 mm
m_2, length of the eye axis calculated from $m=F+r=3.54r=8.0$ mm (Table 11)

though there is a small discrepancy in numerical value between ω_1' and ω_2', and also between d_1 and d_2, the general tendency of coincidence in paired values calculated or measured independently of each other can hardly be denied. The total lens refraction index ($n_2=1.668$) should be estimated as the proper value for marine fish on account

of the coincidence of the directly measured eye axis length with that of the calculated.

In some fishes the existence of Fovea has been demonstrated, for instance in *Siphonostomum typhle* and in *Hippocampus hochgradig* (OPPEL 1914, p. 73). *M. strigatus* has no clear Fovea, but in its retina there is the region of densely populated cones in the central and adjacent backward (outer) part of the retina surrounding processus falciformis (Fig. 7). This region would be estimated as actual Fovea. The adequacy of such microstructural differentiation in the retina has already been touched in the chapter III.

The visual acuity of fish is directly related with the net work of visual cells in the retina, and is not necessarily directly related with the distribution of ganglion cells as BRUNNER (1934) pointed out. Notwithstanding of this, there is, however, a close relationship between cones and ganglion cells so that in the actual foveal region of the retina the number of ganglions pro cone is highest in comparison with other regions of the retina (Table 10). Therefore it may be concluded that the visual acuity of fish is closely, though not directly, related with the distribution of ganglion cells.

HERTER (1929) has demonstrated the relative selection in figural transposition in *Phoxinus laevis* by training the fish to the series of grey paper. MÖRMANN (1934) was of the opinion that honey bee selected figures in relative direction in light and dark shade training, when training number was in medium, and that the honey bee had the tendency to select the figure absolutely when the training was continued many times. *Microcanthus strigatus* exhibited, however obscure, the same attitude towards figural transposition (Table 14) as honey bee, though in the former case striped patterns were used as the training figure.

VIII. Summary

1. The minimal width of striation of a striped pattern discriminated by the coral fish *Microcanthus strigatus* of 10—11 cm in body length, were 0.051—0.077 mm, in average 0.058 mm. 3 fishes among 4 discriminated 0.051 mm width in bright light. The visual angle of these widths seen at 4 cm from the figures were 4′23″—6′35″, in average 4′59″ respectively. The fish was able to discriminate the striped pattern at 4 cm from the figures relatively independently of the width of striation.

2. The visual acuity curve plotted against the log of illumination (Lux) exhibited a continuous double sigmoid form. The functional difference between rods and cones in day and night vision has been clearly demonstrated by this curve.

3. The total refraction index of spherical lens of fish was calculated ($n_2=1.668$) from $n_2=\frac{2.678(m-r)}{2m-3r}$ by the measurement of the lens diameter ($2r$) and the length of eye axis (m).

4. The mean distance of two adjacent cones was calculated by counting the number of cones in a definite area ($93\times93\mu$), and was estimated as 8.4μ in fishes of

10—11 cm body length. The density of cones was highest at the central and adjacent back part of the retina surrounding process falciformis. This region actually seems to be a Fovea, though no clear one could be found morphologically. In this region ganglion cells were more dense than in the other parts of the retina considering the ratio between the number of ganglion cells and the number of cones.

5. The mean distance of cones in the actual foveal area derived from the minimal physiological visual angle was 8.2μ which coincided practically with 8.4μ found independently by the measurement of cone distribution in the retina.

6. The minimal morphological visual angle calculated from minimal physiological visual angle was 3′30″, whereas that of morphologically found by measuring the mean cone distance and the length of eye axis was 3′36″.

7. The change in visual acuity was computated by calculating the visual acuity from the size of lens and mean distance of cones in the retina. The relative visual acuity increased with the growth of fish and approached a constant level when the fish size became 10 cm in length.

8. During the training of fish to vertically striped patterns of different fineness, the selection of test figures by fish was made at first to relative direction in the test of figural transposition, and later an absolute selection surpassed the relative one.

9. The reason why in angling a fine, colorless and transparent fishing line is commonly used, is made clear, and also the differences in visual acuity between fishes with large eyes and those with small ones was discussed on the basis of optical data.

Acknowledgment

The author wishes to express his sincere gratitude to the Director of the Laboratory, Prof. D. Miyadi, for his kind guidance and encouragement.

LITERATURE CITED

Birukow, G. 1937. Untersuchungen über den optischen Drehnystagmus und über die Sehschärfe des Grasfrosches (*Rana temporaria*). Z. vergl. Physiol., Bd. 25, p. 92.

Bröcker, H. 1935. Untersuchungen über das Sehvermögen der Einsiedlerkrebse. Zool Jahrb. Allg. Bd. 55.

Brunner, G. 1934. Ueber dis Sehschärfe der Erlitze (*Phoxinus laevis*) bei verschiedenen Helligkeiten. Z. vergl Physiol., Bd. 21, p. 296.

Buddenbrock, W. von 1952. Vergleichende Physiologie. Bd. I. Sinnesphysiologie. Basel. pp. 120, 192.

Clark, L. B. 1935. The visual acuity of the fidder-crab *Uca pugnax*. J. gen. Physiol., vol. 19.

Crozier, W. J., Wolf, E. E. and Wolf, G. Z. 1938. Critical illumination and flicker frequency in related fishes. J. gen. Physiol. vol. 21, p. 17.

Ehrenhardt, H. 1937. Formensehen und Sehschärfebestimmungen bei Eidechse. Z. vergl. Physiol., Bd. 24, p. 248.

Frisch, K. von 1924. Farbensinn der Erlitze und Duplizitätstheorie. Z. vergl. Physiol., Bd. 2.

HAMILTON, W. F. and GOLDSTEIN. 1933. Visual acuity and accomodation in the pigeon. J. comp. Psychol., vol. 15.
HECHT, S. and WALD, G. 1934. The visual acuity and intensity discrimination of *Drosophila*. J. gen. Physiol., vol. 20.
HECHT, S. and WOLF, E. 1929. The visual acuity of the honey bee. J. gen. Physiol., vol. 12, p. 727.
HERTER, K. 1929. Dressurversuche an Fischen. Z. vergl. Physiol., Bd. 10.
———— 1930. Weitere Dressurversuche an Fischen. Ibid. Bd. 11.
HÖRMANN, M. 1934. Ueber den Helligkeitsinn der Bienen. Z. vergl. Physiol., Bd. 21, p. 188.
HOUSTOUN, R. A. 1924. A treatise on light. London. p. 44.
JOHNSON. 1914. Visual pattern-discrimination in vertebrates. II. J. Animal Behavior, vol. 4, p. 340.
KÖNIG, A. 1897. Die Abhängigkeit der Sehschärfe von der Beleuchtungsintänsität. Sitzber. Akad. Wiss. Berlin.
MATTHIESSEN, L. 1886. Ueber den physikalisch-optischen Bau des Auges der Cetaceen und der Fische. PFLÜGER's Archiv, Bd. 38, p. 521.
OPPEL, A. 1913. Lehrbuch der vergleichenden mikroskopischen Anatomie der Wirbeltiere, p. 72.
LASHLEY. 1932. The mechanism of vision. V. Structure and image forming power of rat's eye. J. comp. Psychol., vol. 13, p. 173.
YAMANOUCHI, T. 1936. The visual acuity of fish. (in Japanese). Zool. Mag., vol. 48, p. 203.

PLANKTON INVESTIGATION IN INLET WATERS ALONG THE COAST OF JAPAN

XIX. REGIONAL CHARACTERISTICS AND CLASSIFICATION OF INLET WATERS BASED ON THE PLANKTON COMMUNITIES[2)]

Isamu YAMAZI
Seto Marine Biological Laboratory, Sirahama

With Plates XVI–XXIII, 4 Text-figures and 3 Tables

CONTENTS

Page
Introduction 157
I. Characteristics of Japanese Inlets 161
a. Characteristics of Inlet Waters 161
b. Quantity of Plankton 163
c. Composition of Plankton 164
d. Ecological Notes of Some Indicator Copepods 165
II. Important Plankton Communities and their Distribution in the Inlet 171
III. Characteristics of Plankton Communities of Japanese Inlets with References to Hydrological Conditions 174
IV. Classification of Japanese Inlets Based on Plankton Communities 180
V. Fluctuations in Plankton Composition 180
VI. Origin of Inlet Plankton 180
VII. Types of Inlets Based on Plankton Community and their Relation to Those on Nekton or Benthos 181
VIII. Inlet Plankton Communities as Indicators 183
a. Of the Stagnation Degree of the Inlet Water 183
b. Of the Biological Conditions for Fisheries and Aquiculture 184
IX. Summary 184
References 185
Explanation of Plates XVI-XXIII 194

Introduction

Although a large number of works have already been published on the productivity and ecology of plankton in various bays or inlet waters, no extensive investigation on the classification of the inlet waters based on the peculiarities of their plankton

1) Contributions from the Seto Marine Biological Laboratory, No. 275.

communities has been made as yet. The works of YOSHIMURA (1934–1936 and 1943) on the classification of inlets with references to the composition of fishes and benthic animals and those of MIYADI (1938–1942) and MIYADI *et al.* (1944, 1947, 1952 and 1954) from the standpoint of the benthic community are the most useful studies available to the biology of the inlet waters in our country. Seasonal changes of plankton composition at regular stations in some inlets along the coast of Japan were

Fig. 1. Map showing the bays and inlets mentioned in this article.

also discussed by many authors (KOKUBO, 1931–1952; SHIMOMURA, 1953; KADO, 1954; ASAOKA, 1955). These works deal chiefly with phytoplankton, but very briefly with zooplankton, and consequently it is difficult to learn from these studies the general indication on the relative abundance of the whole plankton community and its seasonal changes. There are some foreign works which lasted over several years and clarified the seasonal succession of zooplankton. However, the results of these works cannot be compared with the present study, because they do not contain detailed distribution types of plankton within the inlets.

The planktological studies of inlet waters have hitherto been made by the writer (YAMAZI, 1950–1955) intended chiefly to make clear the distribution of plankton in relation to hydrological environments. In this paper, the writer will try to summarize the results of his studies on the plankton communities in Japanese inlet waters with special reference to their regional characteristics and the classification of inlets.

Table 1. Sources of biological and hydrological data quoted in the present study.

Names of Inlets	Location	Authors
Ago	Kii Peninsula	MIYADI (1941); MORISHIMA (1948 b, 1950); TOKIOKA *et al.* (1950 a, b)
Aioi	Inland Sea	KOBE MARINE OBSERVATORY (1935 a, 1937)
Akô	Inland Sea	KOBE MARINE OBSERVATORY (1935, 1937)
Akkesi	Hokkaidô	YAMAZI (1950); MORISHIMA (1955)
Ariake	W. of Kyûsyû	KOBE MARINE OBSERVATORY (1938 c, 1951)
Bungo-suidô	Inland Sea	KOBE MARINE OBSERVATORY (1951)
Habu Harbour	Tôkai Region	MASUI (1941)
Hakodate	Hokkaidô	HABE (1955); HAKODATE MARINE OBSERVATORY (1950); TANITA *et al.* (1950); YAMAZI (1951)
Hirosima	Inland Sea	KOBE MARINE OBSERVATORY (1930, 1936); UDA & WATANABE (1933); YAMAZI (1952)
Hukuoka	N. of Kyûsyû	AIKAWA (1930); MIYADI *et al.* (1942); KOBE MARINE OBSERVATORY (1942)
Hunka	Hokkaidô	KOBE MARINE OBSERVATORY (1934); MURORAN MUNICIPAL OFFICE (1950); TAMURA (1947, 1950); YAMAZI (unpubl.)
Imari	NW. of Kyûsyû	AIKAWA (1930); YAMAZI (1953 a)
Ise	Tôkai Region	KOBE MARINE OBSERVATORY (1933)
Itu	Inland Sea	KOBE MARINE OBSERVATORY (1935, 1937)
Zyûsangata	W. of Tôhoku Dist.	KOKUBO and SATO (1947)
Kagosima	S. of Kyûsyû	KOBE MARINE OBSERVATORY (1933); MIYADI & MASUI (1942); YAMAZI (unpubl.)
Kamaisi	E. of Tôhoku	YAMAZI (1953)
Kii-suidô	E. of Sikoku	KOBE MARINE OBSERVATORY (1930, 1938, 1951–1953)
Kôbe Harbour	Inland Sea	KOBE MARINE OBSERVATORY (1942)
Kozima	Inland Sea	YAMAZI (1954)
Kumihama	San'in District	MIYADI *et al.* (1948, 1950); TATIBANA (1952); YAMAZI (1954); YOSHIMURA (1938)

Names of Inlets	Location	Authors
Maizuru	San'in District	Miyadi *et al.* (1950, 1954); Morishima (1950); Yamazi (1953 a); Furuhashi (unpubl.)
Mikawa	Tôkai Region	Kobe Marine Observatory (1933 a)
Miho	San'in District	Miyadi *et al.* (1952, 1954)
Miyako	E. of Tôhoku	Yamazi (1954 a)
Miyazu	San'in District	Maizuru Marine Observatory (1949); Miyazaki (1952); Habe & Yamazi (1955); Yamazi (1955 a)
Moriura	Kii Peninsula	Yamazi & Horibata (1955 d)
Muroran	Hokkaido	Habe (1953); Yamazi (MS)
Murozu	Inland Sea	Kobe Marine Observatory (1935)
Nagasaki	W. of Kyûsyû	Aikawa (1930); Yamazi (1952)
Nakano-umi	San'in District	Chiba (1948); Kurasige & Kitamura (1933); Kobe Marine Observatory (1931 b); Miyadi & Habe (1945); Miyadi *et al.* (1952, 1954)
Nanao	Hokuriku Region	Habe (1952); Miyadi *et al.* (1942 c); Shimomura (1953); Yamazi (1952 d)
Nemuro	Hokkaido	Yamazi (1950)
Obama	San'in District	Habe *et al.* (1945, 1946); Morishima (1948); Yamazi (1954)
Sagami	Tôkai Region	Aikawa (1936); Marumo *et al.* (1951); Marumo (1951)
Sakagoe	Inland Sea	Kobe Marine Observatory (1935 b)
Seto-naikai (Inland Sea)	Inland Sea	Kobe Marine Observatory (1930 b, 1936 b, 1937, 1942, 1952); Murakami (1954); Maekawa *et al.* (1953)
Suruga	Tôkai Region	Kobe Marine Observatory (1939 a); Aikawa (1936)
Suzaki	S. of Sikoku	Ueda (1950)
Taizi	Kii Peninsula	Yamazi & Horibata (1955 d)
Tanabe	Kii Peninsula	Yamazi(1955c & unpubl. data); Miyadi(1940–41)
Tôkyô	Tôkai Region	Aikawa (1936); Fujiya (1952); Hanaoka *et al.* (1947–1950, 1952); K. M. O. (1931); Masui (1943); Simazu *et al.* (1948); Shimomura (1953); Fisheries Agency (1952 a, b); Yamazi (1955 b)
Toyama	Hokuriku Region	Kobe Marine Observatory (1938); Aikawa (1936)
Tubaki-domari	E. of Sikoku	Kobe Marine Observatory (1936, 1939)
Turuga	San'in District	Yamazi (1954 d); Kobe Marine Observatory (1939)
Urado	S. of Sikaku	Ueda (1950); Miyadi *et al.* (1944)
Uranouti	S. of Sikoku	Miyadi *et al.* (1944); Ueda (1949)
Wakasa	San'in District	Maizuru Marine Observatory (1949); Maéda (1952, 1953 a, b); Miyadi *et al.* (1947, 1949, 1952); Miyairi (1952); Tatibana (1952); Yamazi (1949); Yoshimura (1938)
Yoiti	Hokkaidô	Anraku (1953); Yamazi (1951)
Yura	Kii Peninsula	Habe *et al.* (1945); Yamazi (unpubl. data)
Yamakawa	S. of Kyûsyû	Miyadi *et al.* (1942); Habe (1943)

The author's grateful thanks are due to Prof. Dr. D. MIYADI, Dr. H. UTINOMI and Dr. T. TOKIOKA for their advices and encouragement as well as for their kindness in reading the manuscript. It should be recorded also that this series of investigations was much promoted by the financial aid of the Ministry of Education.

Some of the data about the plankton, benthos, nekton as well as the hydrological environments appearing in this series of reports were cited from the authors listed in Table 1. The locations of inlets mentioned in this paper are shown in Fig. 1.

I. Characteristics of Japanese Inlets

a. Characteristics of Inlet Waters

The complicate coastline of Japan presents a wide variety of environmental conditions, forming shallow and enclosed lagoons on one hand and bays with deep and wide entrances on the other hand. In these bays and inlet waters, the salinity ranges from brackish to oceanic concentration, and the temperature fluctuates from nearly freezing in winter, as on the coast of Hokkaidô, to 29°C or more in summer. The water of the inlets has many important characteristics common to all. Generally it is more variable regionally, seasonally and annually than the open sea water in such characters as transparency, water color, dissolved oxygen contents, hydrogen ion concentration, amount of phosphates and silicates, catalytic activity of sea water, tidal range, degree of stagnancy, salinity and temperature.

Along the coast of the Japan Sea, there are many lagoons isolated from the open sea by sand-bars. The hydrological conditions of these lagoons are more or less peculiar or abnormal as biological environments, e.g. the basin is somewhat deeper than the threshold between the open sea and often holds an azoic zone near its bottom, especially distinctly in the summer season. The summer stagnation is very stable, because the much diluted and heated surface water prevents the vertical circulation, though the degree of stability varies in different inlets or in the different portions of the same lagoon. MIYADI and HABE (1954) classified such disharmonic inlets chiefly on the basis of the "thriving" or "nonthriving" of some indicator animal species, viz. (1) permanent azoic, (2) summer azoic and (3) slightly disharmonic types. The lakes of Hiruga and Suigetu on the Japan Sea coast belong to type 1, the lagoons of Kumihama, Yosanai-kai and Nakano-umi are of type 2. The type 3 is represented by the inner regions of many inlets, e.g. the innermost regions of many inlets near large cities or of lagoons. The deposits of these inlets are often jet black in color and smell of intolerable odour of hydrogen sulphide (YOSHIMURA, 1938, MIYADI *et al.*, 1950; YAMAZI, 1954).

The deepest bays of Japan are Sagami, Suruga and Toyama bays, each having a basin with a depth of about 1500 meters and characterized by the poor development of coastal indentations and the littoral zone. To the bays with basins deeper than 50 meters belong such large ones as Hunka, Aomori, Wakasa and Kagosima as well

as main basins of the Inland Sea (Seto Naikai). Most of the shallow inlets less than 50 meters deep, such as the bays of Tôkyô, Ariake, Ise, Ôsaka, Hirosima and other many small bays or inlets, are characterized by the well development of the beach. Inlets of the last category may be met with most commonly in our country.

The size of Japanese inlets is generally small. Even the largest ones, Iyo-nada and Harima-nada of the Inland Sea, are about 3500 Km^2 in extent. The area of other larger bays is shown in YOSHIMURA's paper (1934).

The bottom texture differs widely in different bays and their different parts. Near the mouth or in the channel where the current is vigorous, the bottom is covered chiefly with gravels, sand and shell fragments. On the contrary, in the inner region where the current is weak, the bottom consists of mud. The innermost region of many bays near cities, and the deeper basin of enclosed lagoons or caldera bays sometimes hold black deposits.

Before going further into the plankton distribution, it may be of some use to give here short sketches of some hydrological characteristics of our inlet waters.

Salinity: Salinity is the best indicator to determine the mixing degree of the sea-water with the fresh-water. And ecologically, the salinity is an important factor limiting the distribution of most plankters and keeping the characteristic inlet plankton community. Generally a fairly clear salinity gradients both horizontally and vertically are observable in most inlet waters, especially markedly in the rainy season from spring to autumn. In some inlets, however, the salinity gradient may be obliterated almost completely in the winter season. In the inlets along the Pacific coast, where the tidal influence is very strong, the vertical stratification of salinity is relatively smaller than that in those along the Japan Sea coast, where the vertical tidal mixing is slight. In the latter inlets, the summer stratification may often persist till winter.

Temperature: The daily and annual cycles of the surface temperature follow rather closely those of the atmospheric temperature at the same location (YAMAZI, 1955 c and d). The studied inlets are located under the influence of either the Kurosio or the Oyasio current area (Fig. 1), i.e. between 31°N (Kyûsyû) and 43°N (Hokkaidô). The average monthly temperature in the south, for example, ranges from about 15°C to 29°C in Kurosio current area, and in the north from about 1°C to 20°C in the Oyasio current area.

Generally the summer surface temperature is the lowest at the mouth part of the inlets and increases towards the inner region, and it is reverse in the case of the winter season. Although the vertical difference of some degrees may be generally observable in the innermost region, it is less pronounced in most of the inlets along the Pacific coast than in those along the Japan Sea, where the thermal stratification is more defined. The high temperature and the low salinity due to the inflows of land drainage caused by heavy rainfalls are the chief characteristics of the summer environment.

Transparency and water color: Both transparency by SECCHI's disc and water

color by FOREL's scale differ in different parts of inlets; the water is generally less transparent and yellowish in color in the inner region, because of the inflow of the land drainage carrying sewage and debris of various sources as well as rich plankton growth. The highest transparency, about 40 meters, was measured in Toyama Bay, where of course the color is bluish.

Dissolved oxygen: The amount of dissolved oxygen is strongly influenced by biological processes. The surface water of the area from the middle region, which is occupied by *Oithona—Paracalanus* community with rich diatoms, to the mouth of bay, where the water is turbulent, is almost supersaturated with oxygen. On the other hand, the oxygen is generally in subsaturation in the innermost region with *Acartia —Oithona nana* community, due probably to the increase of organic matter in the water. In some enclosed inlets, the oxygen demand by organic matters is so high in summer that almost complete absence of oxygen may be observed in the bottom layer.

Hydrogen ion concentration: Usually the horizontal distribution of pH accords well with that of the dissolved oxygen, being higher in the outer region of inlets and lower in the innermost or estuarine regions. The bottom water generally keeps lower pH; this fact is associated with less contents of oxygen, especially distinctly in summer.

Phosphate: The inflow from the mountain region contributes only a small amount of phosphate, while that from the field or cities brings a large quantity of phosphate. The phosphate content is in general higher in the inner region of the inlet than in the outer region, and especially high in strongly stagnant water of enclosed inlets.

Silicate: The silicate content of the inlet water is generally higher than that of of the open sea water. The amount of silicate is a good indicator of the land drainage as well as the salinity and catalytic activity. Actually these three characters are closely related with one another both vertically and horizontally. In deeper layers the amount of silicate is usually small and almost invariable both regionally and seasonally.

Catalytic activity of sea water: The catalytic activity of sea water, which is expressed by the reaction velocity of decomposing hydrogen peroxide, is usually lower in the inner region than in the outer region of inlets; the lower values are generally associated with the larger amount of land drainage. Vertically the values in the surface and bottom layers are lower than those in the middle layer.

b. Quantity of Plankton

The settling volume, number and composition of plankton vary from the inner to the outer part of inlet, because each plankter has its favourable hydrological and topographical conditions. The volume is usually far larger in the middle region than in the innermost or the outer region of inlet. The population of zooplankters, especially of copepods, increases towards the inner region, being the densest in the innermost

region. On the contrary, the numbers of phytoplankters, especially diatoms, are fewer in the innermost region than in outer region, and richest in the middle region where the open sea water and the inlet water rich in nutritive elements are mixed together. The differences of hydrological environments, such as the water movement, salinity and temperature, cause directly or indirectly the local variation in the distribution of inlet plankton.

c. Composition of Plankton

Among the inlet zooplankton, copepods are always the most predominant constituent, though some other animals may sometimes occur in a considerable amount. Larvae of bottom animals, cladocerans, tintinnids and pelagic tunicates are important next to copepods, and chaetognaths, medusae and ostracods occur less numerously or occasionally (Plates XVI–XXIII).

Some of the copepods occur in a considerable number regularly at a certain region and in a definite season. The following species are more important ones because they show typical distribution in the inlet: i.e. *Sinocalanus tenellus*, *Pseudodiaptomus inopinus*, *Acartia clausi*, *A. spinicauda*, *Oithona nana*, *O. rigida*, *Paracalanus parvus* minor form, *Oithona similis*, *Microsetella rosea*, *M. norvegica*, *Centropages* sp., *Temora* sp., *Euterpe acutifrons*, *Oncaea media*, *O. venusta*, *Corycaeus* spp., and some oceanic copepods. The occurrence of *Sinocalanus* and *Pseudodiaptomus* is restricted to estuary or brackish water area of enclosed inlets, where the typical marine copepods are scarce, for instances, the innermost regions of the bays of Kozima, Kumihama and Nakano-umi. The community composed of these two forms is replaced by that of *Acartia* and *Oithona nana* in the adjacent region. *Acartia clausi* and *A. spinicauda* are found in the innermost area, where the water is not so brackish as in the area mentioned above, and decrease steadily towards the outer area of the inlet. These two Acartians are found in same areas but in different seasons. The main area of distribution of *Oithona nana* is the inner region of the inlet, although it may be seen throughout the whole area of the inlet. The minor type of *Paracalanus parvus*, too, occurs more abundantly in the inner and middle regions than in the outer region. *Oithona similis* and *Microsetella* spp. are more important in the outer part than in the inner part of the inlet. *Oncaea* spp., *Corycaeus* spp. and other neritic and oceanic copepods are the inhabitants of the outermost region of the inlet.

Cladocerans of bays are represented by *Penilia schmackeri*, *Evadne tergestina* and *Podon* sp. They are most abundant in the inner and middle parts during the season from early summer to autumn. The inlet chaetognaths *Sagitta delicata*, *S. crassa* and its forma *naikaiensis* occur most abundantly in the inner region from spring to autumn. A pelagic tunicate, *Oikopleura dioica*, is found commonly in the inner region from early summer to early autumn. Tintinnids such as *Tintinnopsis radix*, *Tintinnopsis beroidea*, *Favella taraikaensis*, *Favella ehrenbergii* and *Helicostomella longa* are found in the inner region.

The occurrence of many larval forms of benthic animals such as Echinodermata, Polychaeta, Mollusca, Cirripedia, etc. is one of the characteristic features of the inlet plankton. They appear numerously during spring and summer, although they may be found all the year round.

Doliolums, salpas, oceanic copelates, chaetognaths, and other animals and plants occur chiefly in the outer region of the inlet, where the components of plankton differ widely from those of the inner region.

d. Ecological Notes of Some Indicator Copepods

Acartia clausi Giesbrecht

Acartia clausi is a littoral copepod widely distributed from estuarine to somewhat sheltered waters close to the land (Bigelow, 1926; Deevey, 1946; Wells, 1938; Wiborg, 1940; Wilson, 1932 a, b). In the inlet of Taizi near our laboratory, this species occurs from January to June, the maximum occurrence being in the spring season from April to May, and disappearing when the temperature rises above 25°C or so (Yamazi and Horibata, 1955 d). It is the most important copepod in the innermost part of inlets on our coast (Yamazi, 1951–1955), and may be regarded as a littoral or brackish water form being capable of surviving in waters of various salinities, as low as about 10‰. The water temperature seems to control the occurrence of this species in the inlet. In Taizi bay, the temperature was 13°C and the salinity was about 30‰ in January. In June, the former rose up to 23°–25°C and the latter ranged between 23 and 31‰. It is evident that *Acartia clausi* stands a wide range of temperature and salinity as indicated in my previous papers, although temperature higher than 25°C gives a deliterious effect on this plankton, thus the species disappears completely or is reduced to a very small number in hot summer. *Acartia clausi* is considered to have only one generation in a year and its developmental period is relatively long. The slow development of this species has already been described by Deevey (1948). I am not sure whether a small number of this copepod survives under adversity. However, the prosperity of *A. clausi* in spring was replaced by that of *A. spinicauda* in summer. This alternation of copepod fauna was observed in two successive years, and it may be considered as a regular successional phenomenon to be observed in the inlets on the Pacific coast, or at least near Kii Peninsula.

Acartia spinicauda Giesbrecht

Acartia spinicauda is abundant in the warmer seasons from summer to autumn, occurring in the innermost parts of inlets. It begins to appear when the temperature rises beyond 25°C and continues to thrive till it falls below 20°C. This is a littoral and brackish water form being capable of surviving in waters of relatively low salinity (Yamazi, 1951–1955). Kokubo *et al.* (1947) found this species in a brackish

inlet, Zyûsan-gata in Tôhoku District. In Kozima Bay, it was found in the water with the salinity of as low as 12‰ and above 30‰, and the maximum occurrence was from August to October, decreasing in November and December. As is shown above, this species differs strikingly from *Acartia clausi* in its seasonal occurrence, though their distribution in the inlet is quite similar. The variation of salinity in a wide range do not act effectively on its distribution. *A. spinicauda* seems to be more euryhaline and warm stenothermal than *Acartia clausi*. The observed range was from 20°C to 30°C.

Oithona nana GIESBRECHT

Oithona nana is a small copepod and represents the most abundant and important crustacean in our inlets. Its large stock always contains nauplii and copepodids, besides adults. Although this species is found numerously throughout the year, the number rises sharply during the period from summer to winter. The density of the stock varies from area to area in the inlet. Although it may be found sparsely in the open sea waters close to the land and with higher salinity, it is more common in inlet or estuarine waters of lower salinity. As a whole, its center of distribution is in strongly stagnant water, where *Acartia clausi* and *A. spinicauda* occur, too. LOHMANN (1908) reported the occurrence of this species in the area of low salinity of Kiel Bay and WIBORG (1940) found it in Oslo Fjord in the period from June to February. FARRAN (1911) found it to be common in the coastal waters of the North Sea and the English Channel. The maturation seems to come very rapidly in this species under favourable conditions. TESCH (1915) found that this species had a life cycle of 6–7 weeks along the Dutch coast of the North Sea. MURPHY (1923) pointed out that under experimental conditions, this species had a life cycle of ten weeks.

Oithona rigida GIESBRECHT

Judging from the records of Taizi and Tanabe Bay (YAMAZI, 1955 c; YAMAZI and HORIBATA, 1955 d), this species seems to be an inlet or coastal form. It occurred in the season from late August to December, and began to increase in September to attain the maximum during the period from October to November. Its dense population was found in the inner area rather than in the outer part of the inlet. Thus, this species may take the place of *Oithona nana* during the period when the salinity becomes too high for the latter species.

Paracalanus parvus (CLAUS)

This species is a cosmopolitan. It has been recorded from the tropical and temperate regions of European waters (WIBORG, 1940) and from the tropical and subtropical waters in the west Pacific (MORI, 1937). In Japanese waters two distinct morphological (TANAKA, MS) and ecological types are distidguished in this species,

one is the minor form which thrives in inlet waters and the other is the major form found in outer regions of inlets or in neritic coastal waters (YAMAZI, 1955 c and d; FURUHASI, MS).

The minor form thrives mostly in early summer and autumn, especially remarkably at the inner area of the bay, although it may be found everywhere all the year round (YAMAZI, 1951–1955). In Taizi Bay it occurs in the outer part throughout the year, but most numerously in the summer season. In the bays of Tanabe and Moriura the center of dense population of this species lies in the outer area rather than in the inner part. Thus this species is rather euryhaline; its large population is, however, generally found in more saline areas than in cases of *Acartia* and *Oithona nana*. It seems to tolerate the embaymental environments better than *Oithona similis* does.

Microsetella spp.

Microsetella is one of the common species occurring in the border area between the inlet and the open sea waters, for instance, in the central parts of Tôkyô Bay (YAMAZI, 1955 b) and Hirosima Bay (YAMAZI, 1952 c), where it was found more numerously than in the outer part near the mouth. Although it was found all the year round, the highest density was attained in the summer and autumn (YAMAZI, 1955 d), and the lowest value was found during the season from late spring to early summer. This species is eurythermal, but relatively stenohaline on the Pacific coast, as shown by the fact that it has not been found in abundance or is quite absent in the water of lower salinities, which holds large populations of *Acartia*, *Oithona nana* and *Paracalanus*. Although this species is distributed widely in the oceanic water, its abundant occurrence is restricted to the coastal or inlet waters. *Microsetella rosea* (DANA) is a common warm water form and *Microsetella norvegica* (BOECK) is adapted somewhat to lower temperature than *Microsetella rosea*.

Euterpe acutifrons (DANA)

This species is a neritic and tropical-subtropical form occurring both in the inlets, even in their inner regions, and in the open sea. It is strongly euryhaline and eurythermal; it was found throughout the year in surveyed inlets but the population was always relatively small.

Oithona similis CLAUS

Oithona similis is found in relatively large numbers in the coastal waters or in the outer part of the bay, where this copepod occupies higher percentage of plankton animals than in the inner region. In inlets, a relatively large population occurs during the period from winter to early summer. In general it disappears in the inner region of various inlets, where *Acartia* and *Oithona nana* communities are found. In the northern Atlantic, *Oithona similis* occurs in abundance in inlets for the greater

part of the year (WILSON, 1932; WIBORG, 1940; DIGBY, 1950; DEEVEY, 1952; FISH, 1936; MARSHALL, 1949), and repeats the spawning three or four times a year. It may become adult within two months in favourable conditions. This species is more stenohaline than the preceding species *E. acutifrons*, being never recorded in abundance in the innermost parts with lower salinities. Thus it is considered as a coastal form with a fairly narrow salinity tolerance; the emergence of this species in the inlet is usually attributable to the inflow of the open sea water.

Oncaea spp.

Oncaea occurs sporadically in inlets and is more stenohaline than *Microsetella* and *Oithona similis*. It is distributed widely in the oceanic water, but is more abundant near the coast than in offshore waters. Although it is found all the year round in Japanese waters, it thrives more in summer and autumn. *Oncaea media* GIESBRECHT and *Oncaea venusta* PHILIPPI are the common members of the genus, of which the former is more numerous than the latter. They are carried into the inlets by the inflow of the offshore waters and increase there while the salinity is kept high, but never occur in abundance in the water of low salinity.

Corycaeus spp.

Corycaeus spp. may occupy a higher percentage in total copepods at the entrance of some inlets than any other forms. They are stenohaline and inhabit in the oceanic as well as the coastal water. Usually they are very scarce in inlets throughout the year, excepting occasional appearance in quantity. The abundant occurrence is usually restricted to summer and autumn seasons.

Other Copepods

Other inlet copepods may be grouped as follows: (1) local stock confined chiefly in the inlet and (2) the copepods derived from the open sea or brackish water stocks (YAMAZI, 1955 d). The warm oceanic species are carried into the inlet by currents derived from Kurosio on the Pacific coast or from Tusima Current on the Japan Sea coast. They are numerous in the summer and autumn seasons when the oceanic influx is strong. The cold water species of the inlets originate from the Oyasio on the eastern coast of Hokkaidô and from the Liman Current on the western coast of Hokkaidô during the cold season. The stray copepods from the brackish waters are represented by two important species *Sinocalanus tenellus* KIKUCHI and *Pseudodiaptomus inopinus* BRUCKHARDT; they were found in the innermost region of bays of Kozima, Kumihama and Nakano-umi (YAMAZI, 1954 e).

All the copepods mentioned in this paragraph are quantitatively insignificant in the inlet waters.

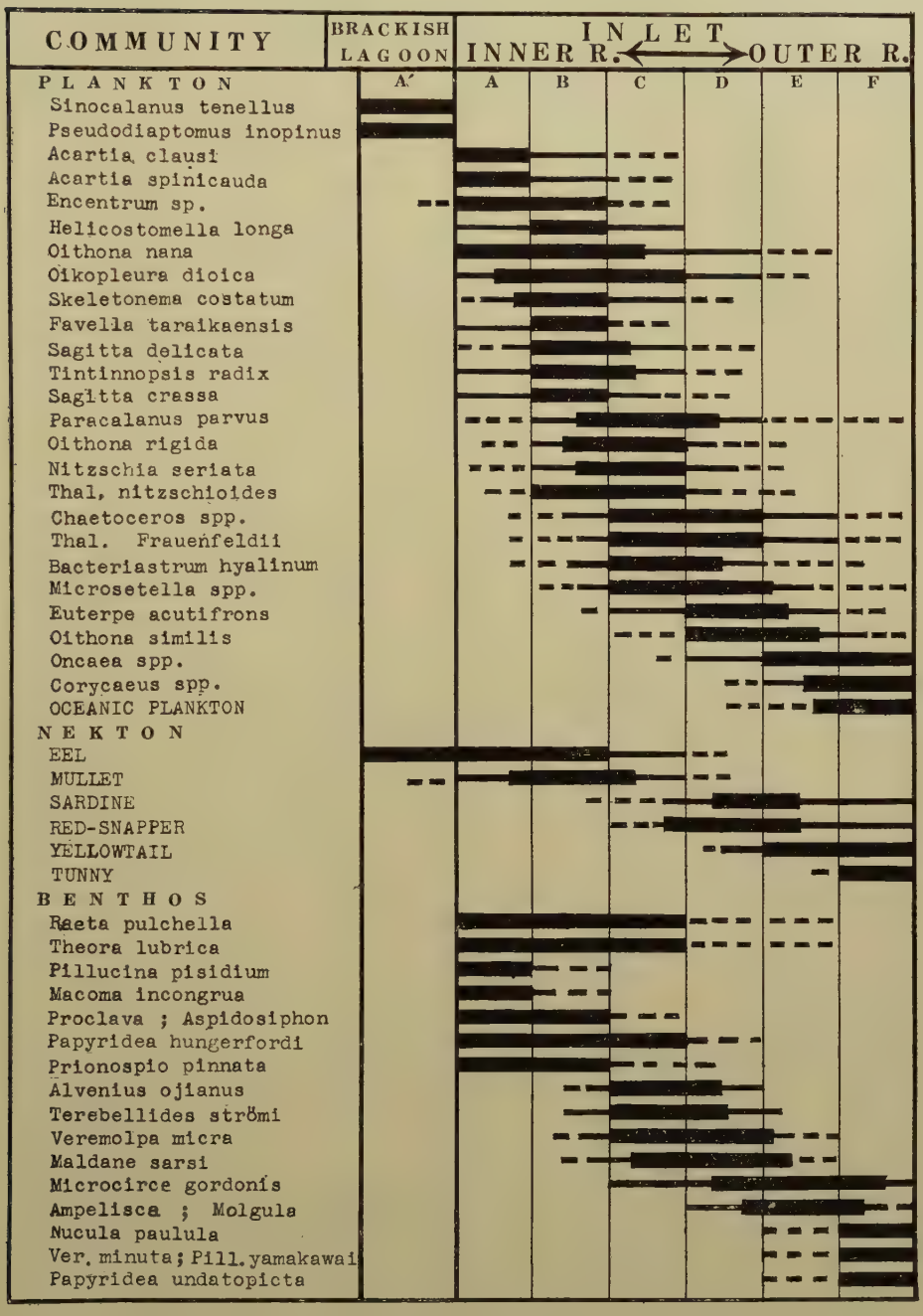


Fig. 2. Distribution of important inlet water organisms.

1
2
3
4
5
6
7
8
1 mm

II. Important Plankton Communities and their Distribution in the Inlet

Although the constituent species of inlet plankton are nearly the same in all inlets of our country, different areas of inlets with different salinities keep their own characteristic plankton communities. Being based upon the results of my previous investigations, the plankton in Japanese inlets may be classified ecologically into the following communities (in each community copepods occupied more than 50% of the total number of zooplankton) and their fasciations (Fig. 2 and Plates XVI–XXIII).

A scheme of the regional distribution of these communities and the relation between them and the hydrological environments are shown respectively in Fig. 3 and Table 2.

***Acartia* community:** This community occupies the innermost region of inlets, adjacent to the brackish water area or the estuary. *Acartia* community (which is dominated with *A. clausi* from spring to early summer and with *A. spinicauda* from summer to autumn) is associated usually with *Oithona nana* and *Paracalanus parvus*, and may be subdivided into fasciations according to the relative abundance of these associates. Other associates are *Sagitta delicata*, *S. crassa*, *S. crassa* f. *naikaiensis*, *Oikopleura dioica* and a small number of brackish water copepods *Sinocalanus tenellus* and *Pseudodiaptomus inopinus*. In the area of this community the animal productivity is relatively high, but the plant productivity is much lower than that in outer areas.

The water is highly stagnant, often yellowish brown in color and of a very small transparency. Both the salinity and catalytic activity of sea water are the lowest here than in the rest of the inlet. Important animals of this area are *Theora lubrica*, *Raeta pulchella*, *Brachidontes senhausia*, *Macoma incongrus*, *Fulvia hungerfordi*, *Pillucina*, *Paphia* and shrimps among the benthos, and eel (*Anguilla japonica*) and mullet (*Mugil cephalus*) among fishes. All these animals are characteristic forms of the area of strongly stagnant water.

***Oithona nana* community:** The population of this community is very dense. It borders with the *Acartia* community along its outer side. It is associated with *Acartia clausi* (from spring to early summer) or *Acartia spinicauda* (from summer

Fig. 3. Microphotographic representation of various plankton communities in inlet waters.

1. *Acartia* community, associated with *Oithona nana* and *Paracalanus parvus* (minor form).
2. *Oithona nana* community, associated with *Acartia spinicauda*.
3. *Oithona nana* community, associated with its nauplii.
4. *Paracalanus parvus* minor form community, associated with *Oithna nana*.
5. *Microsetella* community, associated with *Paracalanus parvus* (minor form) and copepod nauplii.
6. *Oithona similis* community, associated with *Oithona nana*, *Microsetella*, *Paracalanus parvus* (major form) and copepod nauplii.
7. *Oncaea* community, associated with *Paracalanus parvus* (major form), *Oithona similis* and copepod nauplii.
8. Oceanic copepod community.

to autumn), a large number of larval forms, especially copepod nauplii, *Sagitta crassa* f. *naikaiensis* (in summer), *Sagitta crassa* (in winter), *S. delicata, Oikopleura dioica, Tintinnopsis radix, Favella taraikaensis, Helicostomella longa*, and diatoms such as *Skeletonema costatum, Nitzschia seriata, Leptocylindrus danicus, Thalassiothrix Frauenfeldii* and *Chaetoceros* spp. In the intermixing area along its outer region, it is associated with *Paracalanus parvus* and *Oithona similis*. This community is very stable throughout the year as compared with other communities situated more outward. The plankton productivity of the area occupied by this community is very large, although the constituents of this association are somewhat less than those of other communities of outer parts of the inlet. This community may become more monotonous in its composition in the inner region of some lagoons on the coast of Japan Sea or in some secondary baylets in the Inland Sea.

The water holding this community is characterized by high stagnancy, yellowish brown color, small transparency, lower salinities, lower content of phosphates and silicates than in outer areas. Low values of pH and catalytic activity of sea water and the subsaturation of dissolved oxygen are also observed in this part. The benthic animals in this area are *Theora lubrica, Raeta pulchella, Brachidontes senhausia, Macoma incongrua, Fulvia hungerfordi, Pillucina* and *Paphia*, and the nekton is represented by mullet.

***Paracalanus* community:** This community occupies the outer side of the *Oithona nana* community, and borders with *Oithona similis* (or *O. similis* with *Microsetella*) community in its outer part. Other associates are *Euterpe acutifrons, Sagitta delicata, Sagitta crassa, Oikopleura dioica, Encentrum* sp., and diatoms such as *Chaetoceros* spp., *Bacteriastrum hyalinum, Thalassiothrix Frauenfeldii* and *Thalassionema nitzschioides*. The area holding this community can be regarded as an intermixing zone between the inner and outer communities of the inlet. The plankton productivity is the highest and the number of constituents of the community is the largest here throughout the inlet. The water shows higher transparency and salinity, lower water color, less phosphates and silicates, and higher catalytic activity of sea water than in the inner areas. The benthos of the area occupied by this community is characterized by such mollusks as *Alvenius ojianus* and *Veremolpa micra* and the nekton is represented by sardines (*Amblygaster melmosticta, Engraulis japonica* and *Etrumeus micropus*), red-snappers (*Pagrosomus major* and *Evynnis japonica*) and mullet.

***Oithona similis* community:** The representative copepod of the community of the area outer than those mentioned above is *Oithona similis*. The other members are *Paracalanus parvus, Microsetella, Oncaea, Corycaeus*, oceanic copepods and other pelagic animals and plants. The plankton productivity is small here. The water is more saline and transparent than in the preceding areas, but the water color is lower than that of the more outer areas of the bay. Among important associated benthos are such mollusks as *Alvenius ojianus, Veremolpa micra, Nucula paulula, Microcirce*

Table 2. Hydrological characteristics in different areas of the inlet.

Inner Area	Middle Area	Outer Area
Strong Embaymental Conditions	Middle Embaymental Conditions	Weak Embaymental Conditions
(1) Hydrological conditions, especially the salinity, are affected seriously by freshwater discharge and vary in a wide range.	(1) Temperature and salinity vary greatly according to seasons, but their average values are not much different from those in the outer region.	(1) Hydrological conditions, especially, salinity, temperature, catalytic activity, amount of silicates and other nutrient salts are all subjected to the seasonal cycle prevalent in the adjacent open sea.
(2) Salinity shows the maximum vertical variation.	(2) Vertical variation of salinity is slight.	(2) Nearly constant salinity.
(3) Quite independent from direct influences of the open sea.	(3) Slightly affected by the direct influences of open sea.	(3) Vigorous oceanic influences.
(4) Shallow water.	(4) Relatively shallow water.	(4) Deep water.
(5) Least oxygen contents.	(5) Maximum oxygen contents.	(5) Moderate oxygen contents.
(6) Lowest transparency.	(6) Relatively high transparency.	(6) Highest transparency.
(7) Yellowish brown water.	(7) Yellowish green water.	(7) Bluish water.
(8) Large amount of silicates (SiO_2) and phosphates (P_2O_5).	(8) Moderate content of SiO_2 and P_2O_5.	(8) Lowest contents of SiO_2 and P_2O_5.
(9) Lowest value of catalytic activity of sea water.	(9) Relatively high catalytic activity.	(9) Highest catalytic activity.
(10) Strong stagnancy of water.	(10) Medium stagnancy.	(10) Weak stagnancy.

gordonis, and *Pillucina yamakawai*, and among nekton are sardine, red-snapper and yellowtail (*Seriola quinqueradiata*).

***Microsetella* community:** In the middle to the outer region of the bay, where the stagnant water of the inner part and the oceanic water are mixed with each other, an outbreak of abundant *Microsetella* may be observed occasionally. This community is accompanied by *Oithona nana, Paracalanus parvus, Oithona similis, Oncaea* spp., *Oikopleura dioica* and often by a dense mass of diatoms consisting of *Chaetoceros* spp., *Thalassiothrix, Thalassionema*, etc.

***Oncaea* and *Corycaeus* community:** The area exterior to the areas occupied by preceding communities is characterized by abundant occurrence of these species. This community is accompanied by variable amounts of *Paracalanus parvus, Oithona nana, Oithona similis*, oceanic copepods and other animals and plants. Here, the plankton productivity is small, because the water is less stable and the water movement is rapid. The main benthos found in this area are *Nucula paulula, Microcirce gordonis, Veremolpa minuta, Papyridea undatopicta, Pillucina yamakawai* and *Veremolpa micra* and the important nektons are sardine, red-snapper and yellowtail.

Oceanic community: The outermost area of the inlets is occupied chiefly by oceanic animals, diatoms, dinoflagellates and less numerously by some neritic forms. The plankton productivity is very small. The water is very turbulent and characterized by high salinity, high catalytic activity of sea water and low transparency in comparison with those of the inner areas. The water color is bluish, and silicates and phosphate contents are small. The chief associated molluscs are *Nucula paulula, Microcirce gordonis, Veremolpa minuta, Papyridea undatopicta* and *Pillucina yamakawai*, and among nektons are yellowtail, tunny, bonito, etc.

III. Characteristics of Plankton Communities of Japanese Inlets with References to Hydrological Conditions

The biological characteristic of an inlet is closely related with the topographical and hydrographical characteristics. And reversely, the biological characteristics of an inlet are the indicators of the topographical and hydrographical characteristics of the bay. My idea is that the biological characteristics of inlets may be represented by various combinations of plankton communities, which are denominated after some dominant copepods. As indicator copepods were selected common species which occurred widely either in inlet or in the open sea along the coast of Japan. Among such copepods there were some which appeared regularly throughout the year quite indifferently to the environmental conditions, and other which showed regular seasonal succession. Besides copepods, such animals as *Sagitta, Oikopleura*, Cladocera, Rotifera, tintinnid ciliates (*Tintinnopsis, Favella, Helicostomella*) and larvae of invertebrates, and such plants as various diatoms and dinoflagellates are also useful as complementary

indicators of regional characteristics of the inlets. In the following I wish to describe some characteristic combinations (Table 3 and Fig. 4).

Table 3. Combination types of the plankton communities.

	A. clausi or *spinicauda* Community	*O. nana* Community	*P. parvus* Community	*O. similis* or *O. similis* with *Microsetella* Community	*Oncaea* and *Corycaeus* Community	Oceanic copepod Community	Combination types
	A	B	C	D (or D′)	E	F	
More Oceanic ↑ Stronger Embayment ↓	A	B					A—B
	A	B	C				A—B—C
	A	B	C	D			A—B—C—D
	A	B	C	D (or D′)	E		A—B—C—D (or D′)—E
	A	B	C	D (or D′)	E	F	A—B—C—D (or D′)—E—F
			C	D (or D′)	E	F	C—D (or D′)—E—F
	More Oceanic ⟶ ⟵ Stronger Embayment						

1. *Acartia—Oithona nana* (**A—B**) type

Most of the secondary baylets of large inlets, many lagoons on the Japan Sea coast, the inlets having narrow mouths, and shallow estuarine regions near the inner parts belong to this type. These areas are occupied by *Acartia* community consisting of *Acartia clausi* (from winter to early summer) and *A. spinicauda* (from summer to autumn) as well as *Oithona nana* (all the year round) community. *Oithona similis* seldom appears there, except a few individuals which originate from more exterior waters. Occasionally a small number of brackish water copepods, *Sinocalanus tenellus* and *Pseudodiaptomu insopinus*, join these communities. Such inlets having communities dominated by *Acartia* and *Oithona* may be called as A—B type. The inlets of this type are more numerous on the Japan Sea coast than on the Pacific coast. The water belonging to this type are characterized by low transparency, low salinity, low dissolved oxygen content, low catalytic activity of sea water, rich silicates and nutrient salts and high stagnation of water in comparison with that of other types. Even the complete disappearance of oxygen during long summer season may be observed in deeper layer of strongly embayed inlets, where *Oithona* often makes a monotonous community in the upper layer. In the summer season *Paracalanus parvus* is found associated with *Oithona nana* community, as observed in the outer part of Kumihama Bay and Yosa-naikai. In such disharmonic inlets, diatoms, especially *Chaetoceros*,

occur only sporadically, although the nutrient salts are very rich. Zyûsan-gata on the Japan Sea coast and the secondary baylets of the Inland Sea may also be classified in this type, although the latter assumes different aspects during the summer season.

2. *Acartia—O. nana—Paracalanus* (A—B—C) type

In the inlets of this type, *Acartia* and *Oithona nana* communities occur in the inner region, while in the outer region the minor form of *Paracalanus parvus* and *O. nana* are found numerously. Besides the following characteristic associates, there occur a large number of larval forms, especially copepod nauplii and pelecypod veligers: viz. chaetognaths *Sagitta delicata*, *S. crassa* and its forma *naikaiensis*, pelagic tunicate *Oikopleura dioica* and rich diatoms such as *Skeletonema costatum*, *Leptocylindrus danicus*, *Nitzschia seriata*, *Thalassionema*, *Thalassiothrix*, *Chaetoceros* and *Bacteriastrum*. Among all the population of plankton *Oithona nana* is the densest. The water is rich in nutrients, and the phytoplankton flourishes occasionally under favourable condition. The region of lower salinity at the innermost part sometimes keeps a small number of brackish water copepods such as *Sinocalanus* and *Pseudodiaptomus*.

The water of this type is characterized by high stagnancy, yellowish brown color, small transparency, low salinity, high contents of phosphates and silicates, and low pH. The dissolved oxygen is in subsaturation. Similar environments are seen in some secondary inlets of the Inland Sea (the baylets of Matunaga, Akô, Aioi, Sakagoe, Itu, Murozu, Kasaoka and Kôbe Harbour), the western baylet of Nanao, and the bays of Uranouti, Urado, Obama, Ôsaki, etc. Lagoons of Nakano-umi and Kumihama may also belong to this type, although the oxygen content near the bottom decreases remarkably or disappears in summer. Prodigious outbreak of diatoms is seen in some favourable seasons.

The inlets of this type are not always defined by the topographical or hydrological characteristics. There are also some inlets which show intermediate characteristics between A—B—C type and A—B type at some regions and in some seasons.

3. *Acartia—O. nana—Paracalanus—O. similis* (A—B—C—D) type

Acartia clausi (or *spinicauda*), *O. nana*, *Paracalanus* and *O. similis* communities are arranged in this order from the inner to the outer part of the inlet. This combination type of plankton communities is found in large inlets which are connected with the open sea through relatively small entrances or in some secondary baylets of large bays. It is seldom found in small inlets with wide mouth or in bays with large tidal range. The above mentioned circumstance is found more often on the Japan Sea coast, where the tidal range is very small and the water movement is comparatively weaker than on the Pacific coast. The bays of Maizuru, Miho, Akkesi, Nemuro, Muroran and Tubaki-domari are examples of this type.

In the inlets of this type nutrient salts are rich in the inner region. The larger parts of such inlets are occupied by dense A—B—C communities or by intermixed ones of these communities. The density of the population of *Oithona similis* is small. The productivity of diatoms such as *Chaetoceros*, *Bacteriastrum*, etc. and dinoflagellates is prodigious in some favourable seasons. The inner part of the area occupied by A—B—C communities is shallow and rather high in oxygen contents. Associates of this community type are *Oikopleura dioica*, *Sagitta crassa*, *S. delicata*, *Penilia*, *Evadne*, numerous pelagic larvae of polychaetes, decapods, cirripeds, starfishes, sea-urchins, pelecypods and gastropods. The inlets of this type on the Japan Sea coast differ from those on the Pacific coast in having wider inner A—B—C community area and narrower *O. similis* area.

4, a. *Acartia—O. nana—Paracalanus—O. similis—Oncaea* and *Corycaeus* (**A—B—C—D—E**) type

4, b. *Acartia—O. nana—Paracalanus—O. similis* with *Microsetella —Oncaea* and *Corycaeus* (**A—B—C—D′—E**) type

Dense population of *Acartia*, *O. nana*, *Paracalanus*, *O. similis* (or *O. similis* with *Microsetella*) occupies the larger parts of the inlets of this type, except a narrow outer area near the entrance, where *Oncaea* and *Corycaeus* appear in a small number. Following subtypes may be recognized:

A—B—C—D—E type: The arrangement of plankton communities in the area inner than *Oithona similis* community is quite similar to that of the preceding type. The narrow outer part of the bay, however, is occupied by coastal copepods (*Oncaea* and *Corycaeus*), other animals and plants, which are thriving in the open sea water. In such inlets, the water is turbulent in the outer region, where the plankton productivity is relatively small. The area of respective community is nearly equal with one another, no major community being found.

To this subtype belong the inlets of Suzaki, Imari, Moriura, Yura and Hakodate.

A—B—C—D′—E type: The arrangement of the plankton communities is quite similar to that of the preceding subtype, excepting the addition of abundant *Microsetella rosea* or *M. norvegica* in the area between the inner and outer regions, just outside of C or D. The plankton productivity of this subtype is very large, *Chaetoceros* and *Thalassiothrix* being found in quantities in this D′ area; while the productivity drops rapidly in the area outside of the area of *Microsetella*, where many oceanic forms occur in turn. The inlets of this type are usually very complex topographically as well as hydrographically, the water movement being relatively stronger than in the former subtype. The water is transparent, highly saline and very rich in dissolved oxygen throughout the year, especially in the outer region of the inlet. The water of the inner region is characterized by relatively rich nutrient salts.

The bays of Ago, Hirosima, Nagasaki, Tôkyô, Miyazu, Hukuoka, Ariake, Turûga, Mikawa and the larger basins of Inland Sea belong to this subtype.

5. *Acartia—O. nana—Paracalanus—O. similis* (or *O. similis* with *Microsetella*)—*Oncaea* and *Corycaeus*—Oceanic copepod (**A—B—C—D (or D′)—E—F**) type

In many large bays with deep basins and wide entrances, plankton animals, dinoflagellates and diatoms of the coastal and oceanic origin are numerously distributed and occupy a wide area reaching to the central region. The inner part with stagnant water and small secondary baylets of this type are left for A—B—C communities. The population is usually thinner than that of the foregoing types. The bays of Tanabe, Miyako, Ise, Kagosima, Ôsaka, etc. belong to this type.

The water of the inlets of this type shows a great variability from the inner to the outer region. Chemical and physical factors undergo much greater diurnal and seasonal variations in the inner region than in the outer region. In the north baylet of Nanao Bay, bays of Kamaisi, Wakasa and Onagawa, and other baylets with small area, *Acartia* and *Oithona nana* occur in their innermost parts. The main parts of these bays are occupied by C—D (or D′)—E—F communities.

6. *P. parvus—O. similis* (or *O. similis* with *Microsetella*)—*Oncaea* and *Corycaeus*—Oceanic copepod (**C—D (or D′)—E—F**) type

The main part of the bay of this type is occupied by oceanic or coastal water copepods such as the major form of *P. parvus*, *O. similis*, *Microsetella*, *Oncaea* and *Corycaeus*, chaetognaths, tunicates, protozoans, diatoms and dinoflagellates, which are the inhabitants of the warm Kurosio or Tusima current. These forms stay there and establish an oceanic community which are maintained for a considerably long period or being continuously supplied from the coastal or oceanic areas. Larvae of various benthic animals, *Acartia clausi*, *Oithona nana* and their associates are absent, except in the narrow coastal belt of the bays or baylets. The deeper layers of the deep basins of the bays of Toyama, Hunka, Suruga, etc. have the communities of the cold water. The hydrological properties in the main basin, especially salinity, temperature, transparency, water color, amount of nutrient salts, etc. are similar to those in the neritic or oceanic waters, which do not show a great seasonal variation. The plankton productivity is generally low as in the adjacent open sea.

The main basins of Suruga, Hunka (surface layer less than 40 m), Toyama (surface layer less than 100 m), Kii-suidô, Bungo-suidô and Sagami belong to this type which is dominated by oceanic species.

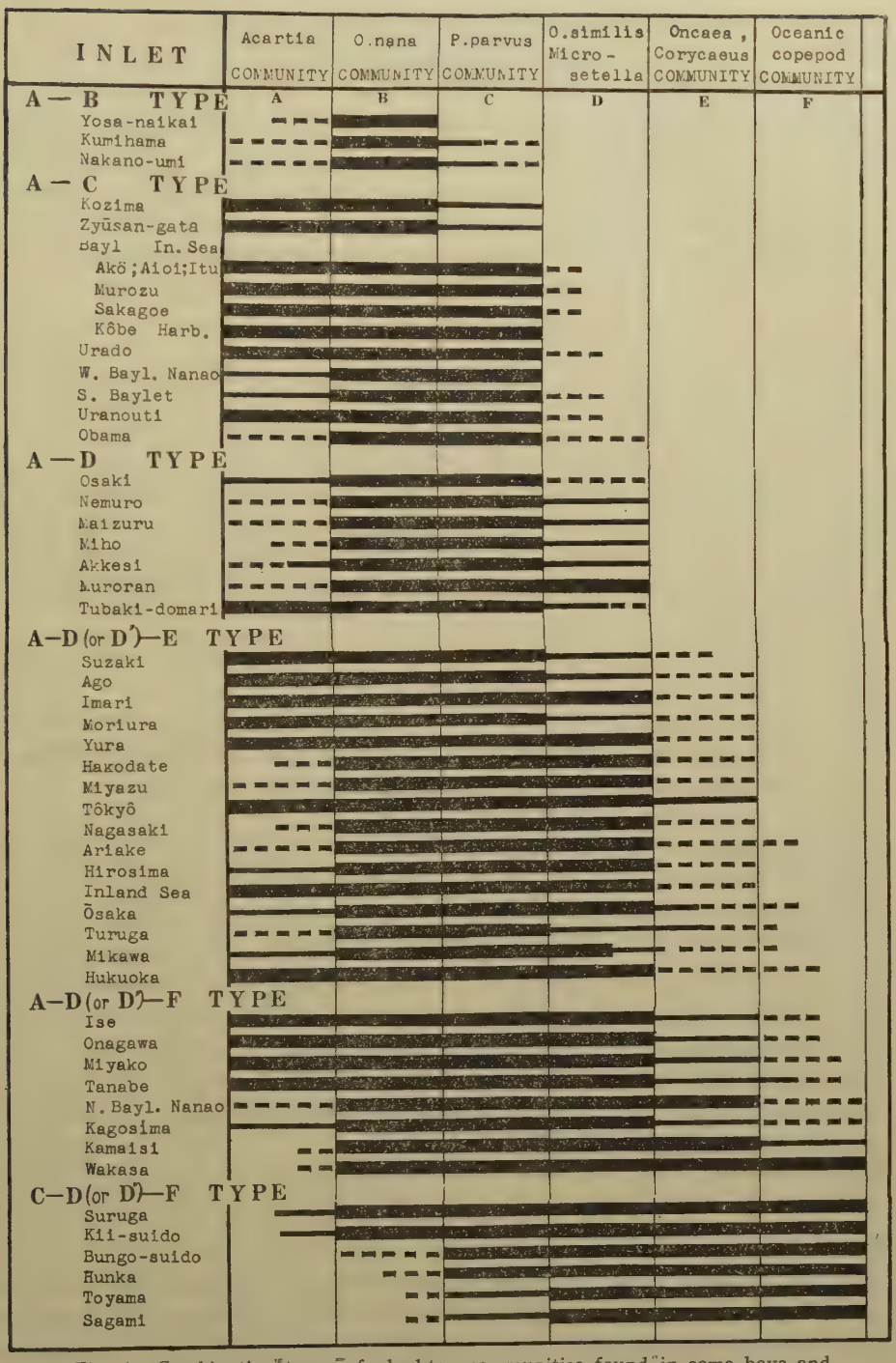


Fig. 4. Combination types of plankton communities found in some bays and inlets on Japanese coasts.

IV. Classification of Japanese Inlets Based on Plankton Communities

As explained in Chapter III, six combination types of plankton communities, being represented by dominant copepods are found in our inlets. In each inlet one of these combination types develops quite regularly, which corresponds to topographical and hydrological conditions, especially the differences of the oceanic influence. These types of combination of important plankton communities are shown schematically in Fig. 3.

V. Fluctuations in Plankton Composition

Seasonal Fluctuation: The regional distributions of plankton, nekton and benthos are influenced by various hydrological and topographical factors. As was shown in my previous papers, among inlet communities, the inner ones such as *Acartia* and *Oithona nana* communities are very stable both seasonally and annually, while those of the outer region such as *Paracalanus parvus* and *Oithona similis* communities are relatively variable, because of the turbulence caused chiefly by the low atmospheric pressure, the southerly summer and northerly winter winds. (YAMAZI, 1955 c and d).

Successional change: The planktological types of inlets naturally change with change in long-run of the topographical and hydrological conditions. As is shown in the inlets of Kumihama, Yosa-naikai, Nakano-umi and Kozima Bay (MIYADI, 1952 and 1954 a; YAMAZI, 1954 a, e), the disharmonic condition which harbours *Oithona* or *Oithona—Paracalanus* communities is related closely with the narrow channel connecting the inlet with the open sea. Most of these bays are lagoons made by the development of sand-bars, and the water is diluted by the strong inflow of freshwater. The influences of either of fresh water or of open sea water change with the development of the sand-bar damming the lagoon. The transformation of the community types in these lagoons from A—B—C—D or A—B—C—D′ to monotonous A—B or A—B—C corresponds to the transition of the embaymental conditions of the inlet from the widely opened bay to the enclosed brackish lagoon, which even holds some brackish water plankters. And finally the transition from the marine communities, i.e. *Oithona similis—Paracalanus—Oithona nana* and *Acartia* community to the brackish water community *Pseudodiaptomus—Sinocalanus* community may be regarded to indicate the increase of the stagnation degree of the inlet water.

VI. Origin of Inlet Plankton

The inlet plankton comes from two sources: (1) a local autogenetic stock and (2) an allogenetic population consisting of both oceanic and coastal forms, i.e. the plankton of warm Kurosio and Tusima current around Honsyû and of cold Oyasio and Liman currents around Hokkaidô. The second population may be brought into

the inlet by the inflow of oceanic water. The following forms are the noticeable warm water autogenetic plankters in Japanese inlets: *Acartia clausi* and *spinicauda*, *Oithona nana* and *rigida*, *Paracalanus parvus* minor form, *Microsetella rosea* and *norvegica* among copepods; *Penilia schmackeri* and *Evadne tergestina* among cladocerans; *Sagitta delicata, crassa* and its forma *naikaiensis*, *Oikopleura dioica*; *Tintinnopsis radix* and *beroidea*, *Favella taraikaensis* and *Helicostomella longa* among protozoans; *Skeletonema costatum*, *Chaetoceros* spp., *Thalassiothrix Frauenfeldii*, *Thalassionema nitzschioides*, *Nitzschia seriata*, *Leptocylindrus danicus*, *Biddulphia* spp., *Asterionella japonica* among diatoms, etc. These inlet forms decrease towards the outer region of the inlet, although they may be observed in a small number in coastal waters of the open sea. Several cold water autogenetic forms such as *Chaetoceros socialis* and *Ch. debilis*, etc. may appear in the inner part of the inlets of the warm region during the short period from winter to early spring.

The allogenetic oceanic or coastal water copepods, pelagic tunicates, chaetognaths, radiolarians and other animals and plants generally decrease toward the inner part of the inlets. Excepting some neritic forms they can not thrive there. The allogenetic warm water species occur more abundantly, during the warm seasons from summer to autumn when the oceanic influx is very strong and the inlet water is renewed in a large scale. The occurrence of cold water oceanic forms is restricted to the cold season except in the inlets of Hokkaidô.

VII. Types of Inlets Based on Plankton Community and their Relation to Those Based on Nekton and Benthos

Historically, KOLKWITZ and MARSSON (1908) established an ecological system for freshwater phytoplankters, which were classified into polysaprobe, α– and β–mesosaprobe and oligosaprobe, according to their reaction to polluted water. LEVANDER (1918) and VÄLIKANGAS (1926) supplemented this system brackish and salt water forms. BRAARUD and BURSA (1939) followed the similar lines of classification as LEVANDER and VÄLIKANGAS, and classified three phytoplankton types in Oslo Fjord, in relation to the contamination of the water, namely polysaprobe (*Eutreptia Lanowi*), mesosaprobe (*Skeletonema costatum*, *Pontosphera Huxleyi*, *Ceratium fusus*, *C. tripos* and *Peridinium trichoideum*) and oligosaprobe (*Nitzschia delicatissima*). NAUMANN (1919) established an ecological system of the freshwater phytoplankton, which corresponds to the chemical characters of the environment, and classified the water into oligotroph, eutroph and heterotroph, and later this system was developed to his classification of lakes from the plant physiological point of view (NAUMANN, 1932). It is natural, however, that the plankton distributions in various inlets on Japanese coasts are different in many ways from those in the freshwaters or Scandinavian fjords. The inlets are always directly connected with the open sea, and this fact is the most important point for the ecological classification of marine plankton, because the

environments of freshwater plankton usually form more or less closed system. Thus, for the establishment of biological types of inlets, there should be other view-points than those for lakes.

MIYADI, MASUI and HABE (1944) studied the distribution of the benthic animal communities, and HABE (1952) discussed on the dead shell accumulations in Japanese inlets from the geographical and ecological points of view. They distinguished three major characteristics in the inlets—strong, middle and weak embaymental characteristics, although the classification of inlets are left for the future. They recognized following facts: the benthic communities characteristic to strong embaymental conditions are the *Terebellides—Maldane* community in the main basin of Tanabe Bay, the mouth region of Ago Bay and the wide area of Gokasyo Bay, the *Cylichna* community in the southern baylet of Nanao Bay and the shallow basins of bays of Ise and Tôkyô, and the *Prionospio* community in the middle region of Ise Bay and the eastern region of bays of Tôkyô and Beppu. With these benthic communities are related usually the shell acumulation consisting of *Alvenius ojianus*, *Veremolpa micra*, *Raeta pulchella* and *Theora lubrica* and *Fulvia hungerfordi*. The weak embaymental conditions sustain such communities as the *Molgula—Caprella* community in the main basin of Matoya Bay, the mouth of Hukuoka Bay, the north and south (at the mouth region) baylets of Nanao Bay, the mouth region of Yura Bay, the *Caprella—Ampelisca* community in the south region of Tôkyô Bay, and the *Ampelisca* community in the channels of Akasi and Yura in Ôsaka Bay and Sakurazima Channel of Kagosima Bay. These communities are associated with the shell accumulation consisting of *Nucula paulula*, *Microcirce gordonis*, *Veremolpa minuta*, *Laevicardium undatopictum* and *Pellucina yamakawai*.

YOSHIMURA (1934–36, 1943) established a comprehensive classification of Japanese Bays on the basis of the distribution of useful nekton and benthos, besides their hydrological conditions. He classified the bays into three major types, namely the shrimp—mullet type (for instance Ariake Bay), the redsnapper—sardine type (Aomori Bay) and the yellowtail type (Sagami Bay). The shrimp—mullet type is subdivided into a) shrimp—sardine subtype to which belong to the bays of Ise and Mikawa, b) laver—mollusca—shrimp subtype to which belong to the bays of Tôkyô, Ariake, Nakano-umi and Matusima, c) eel subtype to which belong Hamana Lake. The redsnapper—sardine type is represented by Kii-suidô, the Inland Sea, Bungo-suidô, bays of Yatusiro, Hukuoka and Aomori. The yellowtail type is subdivided into two subtypes: a) yellowtail—tunny subtype represented by bays of Sagami and Suruga, and b) yellowtail-sardine subtype represented by bays of Toyama, Wakasa and Kagosima. This classification does not include other biological communities.

The communities of *Oithona nana* and *Acartia clausi* or *A. spinicauda* share the same area with the strong embaymental community of MIYADI *et al.*, and YOSHIMURA's fauna characterized by eel, clam, taps, oyster, laver, mullet, shrimp and gilthead. They are frequently accompanied by *Sagitta delicata*, *Oikopleura dioica*, *Tintinnopsis*

beroidea and *T. radix*, *Favella taraikaensis*, *Helicostomella longa*, *Skeletonema*, *Nitzschia*, *Leptocylindrus*, *Thalassionema*, etc.

Paracalanus parvus, *Oithona rigida* and *similis*, *Microsetella* spp., and *Euterpe* occur in the area occupied by MIYADI's middle embaymental community or YOSHIMURA's red-snapper—sardine community. *Oithona nana*, *Sagitta delicata*, *Oikopleura dioica*, *Chaetoceros* spp., *Thalassiothrix*, *Thalassionema*, *Nitzschia* and *Bacteriastrum* are the pelagic associates in this area.

Oncaea media and *venusta*, *Corycaeus* spp., calanoids and other oceanic animals and plants appear in the area characterized by MIYADI's weak embaymental community comprising mackerel horse-mackerel, yellowtail, bonito and tunny.

Thus the distributions of plankton, nekton and benthos in the bay are in good agreement with one another. There is, however, a difference between YOSHIMURA's classification and YAMAZI's one. YOSHIMURA classified the types of relatively large bays or inlets according to the kinds of catches of useful nekton and benthos from their entire area, but payed little consideration to the regional differences in quantity and quality of catches.

Thus, the relation between the inlet types proposed by the two authors may be shown as follow: The inlets of A—B to A—B—C types correspond to A—D or A—D′—E types to the laver—shellfish—shrimp or shrimp—sardine subtypes of the same type, the inlets of A—F type to the sardine subtype of the red-snapper—sardine type or yellowtail—sardine subtype of the yellowtail type, and the inlets of C—D (or D′)—F type to the yellowtail—sardine or yellowtail—tunny subtype of the yellowtail type.

VIII. Inlet Plankton Communities as Indicators

a. As Indicators of the Stagnation Degree of the Inlet Water

As the occurrence of various plankton organisms is regarded as the synthetical result of influences of different environmental factors, the plankton community may be used safely as one of the foremost biological indicators for the nature and circulation of the water mass. The value of the plankton as indicators of the coastal water movements has been discussed by many workers (FRASER, 1952; REDFIELD, 1941; REDFIELD and BEALE, 1940; RUSSELL, 1935 and 1936; SØMME, 1933, 1934; WIBORG, 1954).

The inlets afford a rich variety of hydrological conditions, which are also affected by oceanic influx. The distribution of plankton in the inlet is correlated to the mixing degree of the open sea water with the stagnant water in the inner parts of the inlets (YAMAZI, 1955 a, b, c and d). The inlet waters on Japanese coasts by Kurosio and Tusima Current are characterized by the presence of some warm inlet-water species, which may be used as indicators for pursuing the water masses originated in the inlets. In fact, the courses of water movement as indicated by the distribution of

plankton communities agree well with those traced by drift bottles. Frequently the indicator plankton can suggest of give a clue to the point of dispersion of a certain water mass, where the pursued water is too diluted to be detected by the conventional hydrological methods (YAMAZI, 1955 a and b).

b. As Indicators of the Biological Conditions for Fisheries and Aquiculture

As was shown in our previous paper (YAMAZI and HORIBATA, 1955 d), the yellowtail fishery at the entrance of Taizi Bay is affected strongly by the inflow of the coastal water, which can be ascertained by the existence of a large number of coastal or offshore plankters.

Various hydrological and planktological studies have been made in many inlets in relation to such problems as the spat-falling and fattening of rock oysters, pearl oysters and mussels. Judging from the regional distribution of inlet communities, the spawning and fattening seem to be governed by biological and environmental conditions, which are indicated by the plankton communities. For instance, the rock oysters are naturally found in the areas of *Acartia*, *Oithona nana* and their mixed communities which flourish mostly in inlet of lowest salinity. While the pearl oysters are abundant in the areas where plankton communities are dominated by *Paracalanus*, *O. similis* and *Oncaea*, their geographical distribution in our waters is limited by low temperatures of sea water. According to YAMAMOTO (1953), the spawning of the scallop is related closely to the change of plankton communities, following the sudden seasonal changes in water temperature. The regionally different plankton communities, thus, serve as indicators in finding out the favourable aquicultural conditions for various animals and plants.

IX. Summary

1. In this paper are dealt with the chief features of plankton and hydrological conditions as well as their mutual relationships in the inlet waters along the coast of Japan.

2. The plankton is studied both quantitatively and qualitatively, with special references to the composition of zooplankton in which copepods are always the most important constituents.

3. The distribution types of chief plankton communities of inlet waters on one hand and principal hydrological properties on the other corresponds well with each other, and on these bases we can provide a schematic diagram by which various inlets may be classified biologically.

4. The planktological and hydrological observations in some bays and inlets show that the compositions of zoo- and phytoplankton communities are much influenced by the water movements.

5. A classification of Japanese inlets is attemped here on the bases of plankton communities.

6. The seasonal succession and annual fluctuation of plankton in the inlet waters are studied both quantitatively and qualitatively, and then the regional distributions of plankton communities are discussed. The plankton communities are generally more stable, in all seasons, in the inner region of the inlet than in the outer region. The annual fluctuations in plankton population and specific composition are much larger in the outer region than in the inner region.

7. The inlet plankton originates in two sources: 1) An autogenetic inlet stock and 2) an allogenetic population, the latter of which may be divided into the coastal water forms and the oceanic forms thriving in Kurosio, Tusima Warm Current, Oyasio and Liman Cold Current. The amount of plankton which drift out of the inlets into the adjacent coastal waters seem practically negligible for the most part of Japanese coasts.

8. The relation between the distribution of plankton communites and those of nekton and benthos is discussed in various inlets.

9. The feature of the regional distribution of the inlet plankton communities is useful as an indicator for the stagnation degree or degree of embaymental condition on inlet water. It may be of use for judging the biological conditions for various fisheries or aquiculture.

REFERENCES

Aikawa, H. 1930. The plankton of the southern sea of Japan, considered with references to their hydrography. Rec. Ocean. Wks. Japan, 3 (1), pp. 17–34.

———— 1934. On the quantitative analysis of plankton associations in the seas surrounding Japan, II. Jour. Imp. Exp. Fish. Station, no. 5 (In Japanese with English abstract).

———— 1936 a. On the quantitative analysis of plankton associations in the seas surrounding Japan, VI. Ibid., no. 7 (In Japanese with English abstract).

———— 1936 b. On the diatom communities in the waters surrounding Japan. Rec. Ocean. Wks. Japan, 8, pp. 1–159.

Allen, W. F. 1927. Quantitative studies on inshore marine diatoms and Dinoflagellata of southern California in 1921 and in 1922. Bull. Scripps Inst. Oceanog., Tech. Ser., (2), pp. 19–29, (3), pp. 31–38.

———— 1928. Quantitative studies on inshore marine diatoms and Dinoflagellata in southern California in 1924. Ibid., 1 (15), pp. 347–356.

———— 1930. Quantitative studies of surface catches of marine diatoms and dinoflagellates. Ibid., 2 (10), pp. 389–399.

Anraku, M. 1953. Seasonal distribution of pelagic copepods at Oshoro Bay, West Coast of Hokkaido. Bull. Fac. Fish., Hokkaido Univ., 3 (3), pp. 187–192.

Asaoka, O. 1955. On the variation of the composition of plankton diatoms and the sea at a pier on Jôgasima Island in the period from March 1952 to May 1953. Jour. Ocean. Soc. Japan, 11 (2), pp. 69–74 (In Japanese with English abstract).

Bigelow, H. S. 1926. Plankton of the offshore waters of the Gulf of Maine. Bulletin, U. S. Bur. Fish. (1924), 40 (2), pp. 1–509.

BRAARUD, T. & A. BURSA. 1939. The phytoplankton of the Oslo Fjord, 1933–34. Hvalrådets Skrifter, nr. 19.

CHIBA, T. 1950. A limnological survey of the Nakano-umi and Lake Sinji in the coast of the Japan Sea. II. On the plankton of Nakano-umi in summer (1949). Bull. Jap. Soc. Sci. Fish., 16 (5) (In Japanese with English abstract).

—— 1952. On the plankton of Nakano-umi in summer, 1948. Jour. Shimonoseki Coll. Fish. 2 (1).

DEEVEY, G. B. 1948. The zooplankton of Tisbry Great Pound. Bull. Bingham Oceanogr. Coll., 12 (1), pp. 1–44.

———— 1952 a. A survey of the zooplankton of Block Island Sound, 1943–1946. Ibid., 13 (3), pp. 65–116.

———— 1952. Quantity and composition of the zooplankton of Block Island Sound, 1949. Ibid., 13 (3), pp. 120–164.

DIGBY, P. S. B. 1950. The biology of the small planktonic copepods of Plymouth. J. Mar. Biol. Ass. U. K., N. S. 29, pp. 393–438.

FARRAN, G. P. 1910 and 1911. Copepoda. Bull. trim. Cons. Perm. int. pour l'explor. de la mer. Résumé Planktonique. I and II Cph.

FISH, C. J. 1936. The biology of *Oithona similis* in the Gulf of Maine and Bay of Fundy. Biol. Bull. Woods Hole, 70, pp. 193–216.

FRASER, F. H. 1952. The Chaetognatha and other zooplankton of the Scottish area and their value as biological indicators of hydrographical conditions. Scottish Home Dep., Mar. Res. 1952, no. 2.

FUJIYA, M. 1952. On the seasonal variation of diatoms in Tôkyô Bay. Bull. Naikai Reg. Fish. Res. Lab., no. 2 (In Japanese with English abstract).

GRAN, H. H. & T. BRAARUD 1935. A quantitative study of the phytoplankton in the Bay of Funday and the Gulf of Maine. Jour. Biol. Bd. Canada, 1 (5), pp. 279–467.

HABE, T. 1943. The second survey of the benthic communities of the Yamakawa-ko, with special reference to the deep reduction layer. Jour. Ocean. Soc. Japan, 2 (4), pp. 17–25. (In Japanese).

———— 1944. The studies on the benthos and *Littorina* communities on the tidal zone of Uragami Bay. Ibid., 4 (1) (In Japanese).

———— 1946. Benthic communities of Katuura Bay. Kyôto-daigaku Seiri-Seitai Kenkyû Gyôseki, no. 54 (In Japanese).

———— 1949. Benthic communities and molluscan thanatocoenoses of Tanabe Bay. Bull. Jap. Soc. Sci. Fish., 15 (5) (In Japanese).

———— 1952 a. Benthic communities and molluscan thanatocoenoses of the Nanao Bay. Special Publ. Japan Sea Reg. Fish. Res. Lab. on the 3rd Anniv. of its Founding, pp. 59–64.

———— 1952 b. Molluscan thanatocoenoses of Tôkyô Bay. Bull. Jap. Soc. Sci. Fish., 17 (5) (In Japanese).

———— 1952 c. The accumulation of molluscan shells of the inlet. Tikyû Kagaku, no. 7.

———— 1953. The accumulation of molluscan shells in the bays Hunka and Muroran. Sinseidai no Kenkyû, no. 18 (In Japanese).

———— 1954. The distribution of molluscs in the inlet waters. Zool. Mag., 63 (11 & 12), pp. 483–484.

———— 1955. Molluscan thanatocoenoses of Hakodate Harbour. Sinseidai no Kenkyû, no. 21 (In Japanese).

HABE, T. & YAMAZI, I. 1955. Bio-oceanographical characteristics of the Miyazu-wan. Bull. Biogeogr. Soc. Japan, 16–19.

HABE, T. *et al.* 1945 a. Marine benthic communities of Ôsaki Bay. Kyôto-daigaku Seiri-Seitai Kenkyô Gyôseki no. 21 (In Japanese).

T. Habe *et al.* 1945 b. On the benthic studies of the inlets of the Sea: Benthic communities and molluscan thanatocoenoses of Matunaga Bay. Ibid., no. 22 (In Japanese).

———— 1945 c. The molluscan thanatocoenoses of Obama inlet of Wakasa Bay. Ibid., no. 32 (In Japanese).

———— 1946. Benthic communities of Yura Bay. Ibid., no. 56 (In Japanese).

Hakodate Marine Observatory, 1950. The report of the oceanographical observation in the Hakodate Harbour. Jour. Oceanogr. H. M. O., no. 2.

Hanaoka, T. 1952. On the indicator of production from a water area. Bull. Naikai Reg. Fish. Res. Lab., no. 1 (In Japanese with English abstract).

Hanaoka, T. *et al.* 1947–1950. Res. Rep. Productivity of Inland Sea. Central Fish. Exp. Sta. Tôkyô, nos. 1–8 (In Japanese).

Kado, Y. 1954. The seasonal change of plankton and hydrography of the neighbouring sea of Mukaishima. Jour. Sci. Hirosima Univ., Ser. B, Div. 1, 15 (6).

Kawaguchi, M. 1945. Biological studies on the Inland Sea, II. Benthic communities of Kasaoka Bay during the spring. Kyôto-daigaku Seiri-Seitai Kenkyû Gyôseki, no. 17.

———— 1946. Records on the benthic community of Tôkyô Bay. Ibid., no. 58 (In Japanese).

Kawaguchi, M. & Sirai, K. 1944. Biological studies on the Inland Sea, I. Benthic communities of Kasaoka Bay. Ibid., no. 8.

Kôbe Marine Observayory, 1930 a. Results of the oceanographical observations in Kii Suidô on board the R. M. S. "Syunpu Maru" in winter 1927–28. (1) (2). Jour. Ocean. 1 (1), pp. 1–20; (2), pp. 77 111.

———— 1930 b. Results of the second oceanographical observations in the Ôsaka Wan (Bay) on board the R. M. S. "Syunpu Maru" in 1928. Ibid., 1 (3), pp. 173–367.

———— 1930 c. The results of the oceanographical observations on board R. M. S. "Syunpu Maru" in the Setonaikai (the Inland Sea) in the year 1928, 1929–1930, (part 1) and (part 2). Ibid., 2 (2), pp. 335–433; (4), pp. 537–643.

———— 1931 a. The results of the oceanographical observations on board R. M. S. "Syunpu Maru" in the Tôkyô-wan in the spring, 1929. Ibid., 3 (1), pp. 1–119 (In Japanese with English résumé).

———— 1931 b. The results of the oceanographical observations on board R. M. S. "Syunpu Maru" in the Nakanoumi in the summer, 1929. Ibid., 3 (1), pp. 120–153.

———— 1933 a. The reports of the oceanographical observations on board R. M. S. "Syunpu Maru" in the Ise-no-umi and the Mikawa-wan in Oct., 1929. Ibid., 5 (1), pp. 1–97.

———— 1933 b. The reports of oceanographical observations of the Kagosima-wan and limnological observations of the Ikeda-ko in March 1930. Ibid., 5 (2), pp. 285–396.

———— 1934. Report of the oceanographical observations on board R. M. S. "Syunpu Maru" in the Hunka-wan (Volcanic Bay), Hokkaidô (August, 1932). Ibid., 6 (2), pp. 209–240.

———— 1935 a. Report of the oceanographical observations taken on board R. M. S. "Syunpu Maru" in the Ômura-wan in November and December, 1931. Ibid., 8 (1), pp. 1–164.

———— 1935 b. Report of the oceanographical observations off the Uotukerin (maritime woods for luring fishes) in Nov. 1934. Ibid., 8 (2), pp. 201–212.

———— 1936 a. Report of the oceanographical observations taken on board R. M. S. "Syunpu Maru" in Ôsaka-Wan in April 1935. Ibid., 8 (3), pp. 263–311.

———— 1936 b. Report of the oceanographical observations on board R. M. S. "Syunpu Maru" in the western half of the Seto-Naikai (Inland Sea of Japan) in the winters 1930, 1932 and 1933. Ibid., 9 (2), pp. 101 270.

———— 1937. Results of the oceanographical observations on board R. M. S. "Syunpu Maru" in the Seto-Naikai (Inland Sea of Japan) in the severe winter, February, 1936. Ibid., 10 (1), pp. 45 76.

———— 1938 a. Report of the regular monthly oceanographical observations on board the R. M. S. "Syunpu Maru" in the Ôsaka-Wan and Kii-Suido (1934–1935). Ibid., 11

(2), pp. 221–362.
KOBE MARINE OBSERVATORY, 1938 b. Report of the oceanographical observations on board the R. M. S. "Syunpu Maru" in the Toyama-Wan (1936). Ibid., 11 (3), pp. 509–534.
———— 1938 c. Report of the oceanographical observations on board the R. M. S. "Syunpu Maru" in the Ariake and Yatusiro-Kai (1936). Ibid., 11 (2), pp. 535–610.
———— 1939 a. Report of the oceanographical observations on board the R. M. S. "Syunpu Maru" in Suruga-Wan (Oct.-Nov., 1936). Ibid., 12 (1), pp. 37–72.
———— 1939 b. Report of the oceanographical observations on board the R. M. S. "Syunpu Maru" in Turuga-Wan (Sep.-Oct., 1933). Inbid., 12 (1), pp. 73–78.
———— 1939 c. Report of the oceanographical observations on board the R. M. S. "Syunpu Maru" in the regions close to Uotuke-Hoanrin (1935–1937). Ibid., 12 (2), pp. 175–234.
———— 1941. Report of the oceanographical observations on board the R. M. S. "Syunpu Maru" in the Ariake and Yatusiro-Kai (1936). Ibid., 13 (2), pp. 211–285.
———— 1942 a. The diatoms collected on the oceanographical observations (1934–1935) in Ôsaka Bay. Ibid., 13, pp. 594–638.
———— 1942 b. The dinoflagellates collected on the oceanographical observation (1934–1935) in Ôsaka Bay. Ibid., 13, pp. 639–652.
———— 1942 c. The silicoflagellates collected on the oceanographical observations (1934–1935) in Ôsaka Bay. Ibid., 13, pp. 1100–1128.
———— 1942 d. Report of the oceanographical observations on board the R. M. S. "Syunpu Maru" in the Hukuoka-Wan in April–May, 1940. Ibid., 13 (3), pp. 481–548, (3), pp. 928 969.
———— 1942 e. Report of the oceanographical observations on board the R. M. S. "Syunpu Maru" in the Seto-Naikai (Inland Sea) 1938–1939). Ibid., 13 (4), pp. 801–865.
———— 1942 f. Report of the oceanographical observations on board the R. M. S. "Syunpu Maru" in the Kobe Harbour in April, 1941. Ibid., 13 (4), pp. 928–969.
———— 1951–1953. Report of the oceanographical observation on board the R. M. S. "Syunpu Maru" in Kii-Suido. Ibid., 2nd Series, 1–4.
———— 1951–1953. Results of the regular monthly oceanographical observations on board the R. M. S. "Syunpu-Maru" in the Ôsaka Wan. Ibid., 1–4.
———— 1952. Meteorology and oceanography in the Seto Inland Sea. Bull. Kobe Marine Observatory, no. 161.
———— 1951–1952. Report of the Plankton. Huyû-Seibutu Sokuhô no. 5–8.
KOKUBO, S. 1931–1940. Planktological Review, no. 1–15, Nat. Res. Council of Japan (In Japanese).
———— 1932. Quantitative studies on microplankton in Aomori Bay during 1929–1930. Rec. Ocean. Wks. Japan, 4 (1), pp. 171–244; Jour. Fish., no. 35 (In Japanese).
———— 1945–1949. Bulletin of the marine Biological Station of Asamushi. vols. 1–5.
———— 1950. On the plankton of Mutu Bay. Reg. Fish. Rec. Aomori Prefecture, 1, pp. 99–122.
———— 1952. Results of the observations on the plankton and oceanography of Mutu Bay during 1950. Reference being made also to the period 1946–1950. Bull. Mar. Biol. Station, Asamushi, 5 (1–4), pp. 1–54.
KOKUBO, S. & T. TAMURA 1934. On the seasonal and vertical distribution of the plankton of Aomori Bay. Sci. Rep. Tôhoku Imp. Univ., 4th Ser., Biol., 8 (4), pp. 297–333.
———— & ———— 1938. Observations on the plankton and hydrographic conditions of Aomori Bay. During the period 1933–1935. Rec. Ocean. Wks. Japan, 10 (1), pp. 1–15.
KOKUBO, S. & S. SATO 1947. Planktons in Jû-san Gata. Physiol. and Ecol., 1 (4).
KOLKWITZ, R. & M. MARSSON 1908. Ökologie der pflanzlichen Saprobien. Ber. d. deutsch. Bot. Ges. 1908., 26 a.
KURASIGE, H. & K. KITAMURA 1933. On the "Akasiwo" caused by diatom at the Nakano-umi.

Jour. Meteor. Soc. Japan, 2nd Ser., 12 (6), pp. 287–300 (In Japanese).

LEVANDER, H. 1918. Meddelande om Helsingfors hamnplankton. Meddel. Soc. Fauna & Flora Fennica, 44, Helsingfors.

LOHMANN, H. 1910. Untersuchungen zur Feststellung des vollständigen Gehaltes des Meeres an Plankton. Komm. Wissenschaftl. Meeresunt. Biol. Anst. Helgoland, Abt. Kiel., 10.

MARSHALL, S. M. 1949. On the biology of the small copepods in Loch Striven. J. Mar. Biol. Assoc. U. K., N. S. 28, pp. 45–122.

MAÉDA, H. 1952. Studies on Yosa-Naikai. 1. On the over-saturation of dissolved oxygen and vertical changes of pH in winter. Umi to Sora (Sea and Sky), 29 (5/6), pp. 89–95 (In Japanese with English summary).

———— 1953 a. Ditto. 2. Considerations upon the range of the saturation and the influences by the river Noda and the open Sea. Jour. Shimonoseki Coll. Fish., 3 (2), pp. 133–140.

---- —— 1953 b. Ditto. 3. Analytical observation of the influence of the river Noda and the benthic communities. Ibid., 3 (2), pp. 141–149.

MAEKAWA, K. *et al.* 1953. On the seasonal change of oceanographical condition and the plankton in Suho Nada. Naikai Exp. Fish. Stat. Yamaguti Prefecture, 5 (1) (In Japanese).

MAIZURU MARINE OBSERVATORY 1949. The results of the oceanographical observation on Miyazu Bay and Yosa-Naikai. Oceanographical Data, no. 10.

———————— 1952. The report of the oceanographical observation in the western part of Wakasa Bay on board the R. M. S. "Kurosio Maru" (Feb. 29–March 2, 1952). Ibid., 1 (3/4), pp. 71–81 (In Japanese with English abstract).

MARUMO, T. *et al.* 1951 a. On the diurnal variation of planktological conditions at the centre of Sagami Bay. I, II and III. Oceanogr. Rep. Centr. Meteor. Obs., 2 (1) (In Japanese with English abstract).

———————— 1951 b. On the planktological conditions of Sagami Bay from September, 1947 to July, 1948. Ibid., 2 (1).

MASUI, T. 1941. The benthic communities of the Habu-ko with special reference to the sulphides in sediments. Jour. of Fish., no. 49, pp. 66–71 (In Japanese with English résumé).

———— 1943. The benthic communities of Tôkyô Bay. Jour. Ocean. Soc. Japan, 3 (2), pp. 130–141 (In Japanese).

MATSUDAIRA, C. 1940. Seasonal change of chemical composition of sea water and phytoplankton in the Bay of Ise. Suisan Gakukaihô, 8 (2), pp. 148–162 (In Japanese).

MIYADI, D. 1938. Quantitative studies on the benthic communities of the Ôsaka Wan, I. Umi to Sora (Sea and Sky), 18, pp. 172–184.

———— 1938. Preliminary reconnaissance on the benthic communities of the Tanabe-wan. Bull. Jap. Soc. Sci. Fish., 7, pp. 176–178 (In Jap. with Engl. synopsis).

———— 1940. Quantitative studies on the benthic communities of the Ôsaka-wan, II. Nippon Gakuzyutu-kyôkai Hôkoku, 15 (3).

———— 1940. Marine benthic communities of the Ôsaka-wan. Jour. Ocean., 12 (2), pp. 371–385.

———— 1940. Marine benthic communities of the Tanabe-wan. Annot. Zool. Japon, 19 (4).

———— 1941a. Indentation individuality of the Tanabe-wan. Mem. Imp. Mar. Observ., 7 (4).

———— 1941b. Marine benthic communities of the Beppu-wan. Ibid., 7 (4).

———— 1941c. Marine benthic communities of the Ise-wan and the Mikawa-wan. Ibid., 7 (4).

———— 1941.d. Ecological survey of the benthos of the Ago-wan. Annot. Zool. Japon., 20 (3).

MIYADI, D. *et al.* 1942 a. Marine benthic communities of the Kagosima-wan and Yamakawa-kô. Jour. Ocean., 13 (3) (In Japanese).

———————— 1942 b. Marine benthic communities of the Hukuoka-wan. Umi to Sora, 22 (7), pp. 232–251 (In Japanese).

———————— 1942 c. Studies on the benthic communities of the Nanao-wan. Jour. Ocean.

Soc. Japan, 2 (1) (In Japanese).

MIYADI, D. *et al.* 1944 a. On the correlation between the embaymental degree and the distribution of the benthos on the bottom and tidal zone of Uranouti Bay. Ibid., 3 (4), (In Japanese).

———— 1944 b. The embaymental degree of Urado Bay. Ibid., 4 (1) (In Japanese).

———— 1944 c. On the relation between the embaymental degree and distribution of the communities. Kyôto-daigaku Seiri-Seitai Kenkyû Gyôseki, no. 3.

———— 1945. Benthic communities and thanatocoenoses of Nakano-umi. Ibid., no. 31, pp. 1–24.

———— 1947. On the thanatocoenoses of bays. Physiol. and Ecol., 1 (2), pp. 110–124 (In Japanese with English résumé).

———— 1947 a. On the hydrographical succession of the Yosa-naikai and the decline of its fisheries. Zool. Mag., 57 (9), pp. 147–151 (In Japanese with English summary).

———— 1949. Studies on the Yosa-Naikai, its oceanographic conditions and their improvement for fisheries purposes. Bull. Jap. Soc. Sci. Fish., 14 (5), pp. 244–250 (In Japanese with English abstract).

———— 1950 a. On the benthos and shell deposits of Kumihama Bay ; a lagoon on southwestern Japan Sea coast. Stud. Aquat. Anim. Japan, I, pp. 25–32, (5)–(6) (In Japanese with English summary).

———— 1950 b. Benthonic biocoenoses and thanatocoenoses of the Maizuru Bay. Ibid.

———— 1952. The biological studies of bays of Miho and Nakano-umi (I). Kyôto-daigaku, Seiri-Seitai Kenkyû Gyôseki, no. 76 (In Japanese).

———— 1954 a. Idem. (2). Ibid., no. 78 (In Japanese).

———— 1954 b. Biological succession in disharmonic bays and lagoons, and their improvement for fisheries purposes. Proceedings Seventh Pacific Science Congress, 4.

MIYAIRI, T. 1952. Studies on the constituents of the water and fisheries status in the Inland Sea of Yosa. Special Publ. Japan Sea Reg. Fish. Lab., on the third Anniv. Found., pp. 193–202 (In Japanese with English abstract).

MIYAMOTO, H. *et al.* 1954. Fishing situations of the yellowtail in the Pacific coast, 1950–1951 through 1952–1953 seasons. Bull. Tôkyô Reg. Fish. Res. Lab., no. 8 (In Japanese with English abstract).

MORISHIMA, M. 1947. The accumulation of foraminiferal tests in the inlets of Obama and Maizuru. Physiol. and Ecol., 2 (3).

———— 1948 a. The accumulation of foraminiferal tests in inlets of Wakasa Bay on the Inland Sea of Japan. Rep. Com. Treat. Mar. Ecol. Paleoecol., Nat. Res. Coun., Washington, no. 7.

———— 1948 b. Foraminiferal thanatocoenoses of Ago Bay, Kii Peninsula, Japan. Ibid., no. 8.

———— 1955. Foraminiferal thanatocoenoses of Akkeshi Bay and its vicinity. Memoirs Coll. Sci. Univ. Kyôto, Ser. B, 20 (2), pp. 113–117.

MORI, T. 1937. The pelagic Copepoda from the neighbouring waters of Japan. Yôkendo Co., Tôkyô.

MURAKAMI, A. 1954. Oceanography of Kasaoka Bay in Seto Inland Sea. Bull. Naikai Reg. Fish. Res. Lab., no. 6 (In Japanese).

MURPHY, H. 1923. The life cycle of *Oithona nana*, reared experimentally. Univ. California Publ. Zool. 22 (13).

MURORAN MUNICIPAL OFFICE 1950. Reports of Oceanographical Observations taken in the Funka Bay, during the period 1948–1950.

NAIKAI REG. FISH. RES. LAB. 1951–1955. Report of Inland Sea Fish. Co-oper. Investig. Ser. A, no. 1–11 (In Japanese).

NAUMANN, E. 1919. Några synspunkter angående limnoplanktons ökologi med särskild hänsyn till fytoplankton. Svensk Bot. Tidskr., 13 (2).

———— 1932. Grundzüge der regionalen Limnologie. Die Binnegewässer. Bd. XI, Stuttgart.

OKITSU, T. 1953. Observation on the seasonal changes of phytoplankton in Aomori Bay during 1951. Bull. Mar. Biol. Stat. Asamushi, 6 (1-4).

REDFIELD, A. C. 1941. Effects of the circulation of water on the distribution on the calanoid community in the Gulf of Maine. Biol. Bull., 80, pp. 86-110.

REDFIELD, A. C. *et al.* 1940. Factors determining the distribution of populations of chaetognaths in the Gulf of Maine. Ibid., 79, pp. 459-487.

RUSSELL, F. S. 1935. On the value of certain plankton animals as indicators of water movements in the English Channel and North Sea. Jour. Mar. Biol. Ass. U. K., N. S., 20 (2), pp. 309-332.

———— 1936. Observations on the distribution of plankton animals made on Col. E. T. Peel's Yacht "St. George" in the mouth of English Channel, July, 1935. Ibid., 20, pp. 507-522.

———— 1939. Hydrological and biological conditions in the North Sea as indicated by plankton organisms. Jour. du Conseil, 14 (1), pp. 171-192.

SHIMAZU, T. & K. YAMANE 1948. Studies on the benthos of Tôkyô Bay (1). On the seasonal changes of temperature of bottom with reference to the benthos. Bull. Jap. Soc. Sci. Fish., 14 (1), pp. 51-55 (In Japanese with English synopsis).

SHIMOMURA, T. 1953. A study on the production and distribution of the microplankton and their relation to oceanographic conditions. I, II and III. Bull. Japan Sea Reg. Fish. Res. Lab., no. 3 (In Japanese with English abstract).

———— 1953. Planktological study on the propriety of culture or multiplication in Nanao Bay, Ishikawa Pref., Ibid., no. 3 (In Japanese with English abstract).

———— 1954. Planktological study on the warm Tushima Current region. I and II. Ann. Rep. Japan Sea Reg. Fish Res. Lab. no. 1.

TAMURA, T. 1947. The report of the oceanographical observation in Hunka Bay. Jour. Oceanogr. H. M. O. no. 2, pp. 144-167 (In Japanese).

———— 1950. Annual change of occurrence of plankton in the vicinity of Muroran. Report on the oceanographical observations of Volcano Bay, Hokkaido Muroran Municipal Office, pp. 63-83 (In Japanese).

———— 1951. On the seasonal change of the plankton making their appearance in the vicinity of Funka-Bay. Sci. Pap. Hokkaido Fish. Sci. Inst. no. 8, pp. 26-38 (In Japanese).

TANAKA, O. 1956. The pelagic copepods of the Izu region, middle Japan. Systematic account, I. Calanidae and Eucalanidae. Publ. Seto Mar. Biol. Lab., 5 (2), pp. 251-272.

TANITA, S. *et al.* 1950. Studies on the environmental conditions of shellfish field. 1. In the case of Hakodate Harbour. Bull. Fac. Fish., Hokkaidô Univ., 1 (1), pp. 1-10.

TESCH, J. J. 1915. Quantitative Untersuchungen über das Vorkommen des Copepoden und ihrer Entwicklungsstadien im Plankton beim Haaks-Feuerschiff (1912). Mit einem Anhang. Rapp. Verhandl. Rijksinst Visscherijonderz. I, 3, Helder.

TOKIOKA, T. 1939. Notes on chaetognaths and pelagic tunicates of Ôsaka Bay. Umi to Sora, 19, pp. 152-160 (In Japanese).

TOKIOKA, T. & I. YAMAZI, 1950. Studies on the pearl fishing ground of Ago Bay. II and III. Kyôto-daigaku Seiri-Seitai Kenkyû Gyôseki, no. 70, pp. 5-18 and no. 71, pp. 19-61 (In Japanese).

TOKIOKA, T., I. YAMAZI & S. FUSE, 1951. Idem. V. Estimation of the hydrographical and hydrobiological influences of Hukaya Channel upon Hunakosi baylet in Ago Bay. Ibid., no. 73, pp. 19-61 (In Japanese).

TSUJITA, T. 1953. A marine ecological study on the Bay of Ômura. Jour. Ocean. Soc. Japan, 9 (1), pp. 23-31 (In Japanese with English abstract).

UDA, M. *et al.* 1934. The catch of kiddle nets in two fishing grounds on the coast of Nagasaki

Prefecture and Izu Peninsula. Bull. Jap. Soc. Sci. Fish., 2 (4), pp. 190–198 (In Japanese with English summary).

UEDA, M. 1949. Hydrological observation on the Uranouchi Bay. Ibid., 15 (4), pp. 190–198 (In Japanese with English summary).

———— 1950. Biological and limnological conditions in Urado Bay and Suzaki Bay. Hirooka Agric. High School, in Kôti Prefecture (In Japanese).

VÄLIKANGAS, I. 1926. Planktologische Untersuchungen im Hafengebiet von Helsingfors. 1. Über das Plankton insbesondere das Netz-Zooplankton des Sommerhalbjahres. Acta zoologica Fennica 1. Helsingfors.

WELLS, A. L. 1938. Some notes on the plankton of the Thames estuary. J. Anim. Ecol., 7, pp. 105–124.

WIBORG, K. F. 1940. The production of zooplankton in the Oslo Fjord in 1933–1934 with special reference to the copepods. Hvålradets Skrifter., no. 21, pp. 1–85.

———— 1954. Investigations on zooplankton in coastal and offshore waters of western and northwestern Norway. With special reference to the copepods. Rep. Norw. Fish. and Mar. Inv., 11 (1).

WILSON, C. B. 1932 a. The copepods of the Woods Hole region, Massachusetts. Bull. U. S. Nat. Mus., no. 158, pp. 1–635.

———— 1932 b. The copepod crustaceans of Chesapeake Bay. Proc. U. S. Nat. Mus., 80 (15), pp. 1–54.

WILSON, D. P. 1951. A biological differences between natural sea waters. Jour. Mar. Biol. Assoc. U. K., 30 (1).

YAMAMOTO, G. 1951 a. Ecological note on transplantation of the scallop, *Pecten yessoensis* Jay, in Mutu Bay, with special reference to the succession of the benthic communities. Sci. Rep. Tôhoku Univ. 4th Ser. 19, pp. 11–16.

———— 1951 b. Benthic communities of Mutu Bay. Bull. Jap. Soc. Sci. Fish., 16 (16).

———— 1952. Further study on the ecology of spawning in the scallop, in relation to luner phases, temperature and plankton. Ibid., 19, pp. 247–254.

———— 1953. Ecology of the scallop, *Pecten yessoensis* Jay. Ibid., 20 (1), pp. 11–32.

YAMAZI, I. 1950. Plankton investigation in inlet waters along the coast of Japan. I. Introductory notes and the plankton of Akkesi Bay, Hanasaki Inlet and Nemuro Harbour. Publ. Seto Mar. Biol. Lab., 1 (3).

———— 1951. Idem. II. The plankton of Hakodate Harbour and Yoichi Inlet in Hokkaidô Ibid., 1 (4).

———— 1952 a. Idem. III. The plankton of Imari Bay in Kyûsyû. Ibid., 2 (2).

———— 1952 b. Idem. IV. The plankton of Nagasaki Bay and Harbour in Kyûsyû. Ibid., 2 (2).

———— 1952 c. Idem. V. The plankton of Hirosima Bay in the Seto-Naikai (Inland Sea). Ibid., 2 (2).

———— 1952 d. Idem. VI. The plankton of Nanao Bay. Bull. Japan Sea Reg. Fish. Rea. Lab. Special vol.

———— 1952 e. Seasonal succession of the plankton at the shell-fish ground of Ariake Bay, Hukuoka Prefecture. Senkai Zôsyoku Tyôsa Hôkoku, Fish. Agency. no. 1.

———— 1953 a. Plankton investigation in inlet waters along the coast of Japan. VIII. The plankton collected during the cruises to the New Yamato Bank in the Japan Sea. Publ. Seto Mar. Biol. Lab., 3 (1).

———— 1953 b. Idem. IX. The plankton of Onagawa Bay on the eastern coast of Tôhoku District. Ibid., 3 (2).

———— 1953 c. Idem. X. The plankton of Kamaisi Bay on the eastern coast of Tôhoku District. Ibid., 3 (2).

YAMAZI, I. 1954 a. Idem. XI. The plankton of Kozima Bay in the Seto-Naikai (Inland Sea). Ibid., 3 (3).
———— 1954 b. Idem. XII. The plankton of Miyako Bay on the eastern coast of Tôhoku District. Ibid., 3 (3).
———— 1954 c. Idem. XIII. The plankton of Obama Bay on the Japan Sea coast. Ibid., 4 (1).
———— 1954 d. Idem. XIV. The plankton of Turuga Bay on the Japan Sea coast. Ibid., 4 (1).
———— 1954 e. Idem. XV. The plankton of Yosa-Naikai and Kumihama Bay, enclosed bays on the Japan Sea coast. Ibid., 4 (1).
———— 1955 a. Idem. VIII. The distribution of plankton in Miyazu Bay in relation to the water movement. Ibid., 4 (2).
———— 1955 b. Idem. XVI. The plankton of Tôkyô Bay in relation to the water movement. Ibid., 4 (2).
———— 1955 c. Idem. XVII. Seasonal succession of zooplankton in the inner area of Tanabe Bay from June to October, 1954. Ibid., 4 (2).
YAMAZI, I. & T. HORIBATA 1955 d. Idem. XVIII. Seasonal succession of plankton in Taizi Bay in the years 1951–1953. Ibid., 4 (2).
YASUI, Z. 1930. Topographical features of the Inland Sea. Umi to Sora, 10, pp. 181–185.
YOSHIMURA, S. 1931. Vertical distribution of sulphide in Suigetu-ko and Hiruga-ko, Hukui. Jap. Jour. Limnol., 1 (1), pp. 44–46 (In Japanese).
———— 1934–1936. General oceanographical studies of inlets: A comparison between inshore feature and offshore feature. Chiri Kyôiku, 20 (1), pp. 22–29; (2), pp. 160–165; (4), pp. 415–422; (5), 515–519; 21 (1), pp. 46–51; (3), pp. 285–290; (6), pp. 645–649; 23 (1), pp. 43–50; (4), pp. 404–410; (5), pp. 528–530 (In Japanese).
———— 1934 a. Oceanographical classification of the Japanese inlet. Geogr. Rev. Jap., 10 (6), pp. 533–535 (In Japanese).
———— 1934 b. The areas and depths of inlet waters in the main land of Japan. Jour. Geography, 46 (543), pp. 245–246 (In Japanese).
———— 1943. A system of inlets in the main land of Japan based on the catches of coastal fisheries: A general oceanographical investigation. (1). Papers Ôtuka Geogr. Soc., no. 3, pp. 113–136 (In Japanese).

EXPLANATION OF PLATES XVI–XXIII

PLATE XVI

Fig. 1. *Pseudodiaptomus inopinus* BRUCKHARDT, female, dorsal and lateral sides. ×40.
Fig. 2. *Sinocalanus tenellus* KIKUCHI, female, dorsal and lateral sides. ×40.
Figs. 3A–C. *Acartia spinicauda* GIESBRECHT. A, Female, dorsal side. ×40; B, 5th feet of female. ×240; C, Male, dorsal side. ×40.
Figs. 4A & B. *Acartia clausi* GIESBRECHT. A, Female, dorsal side. ×40; B, Male, dorsal side. ×40.
Fig. 5. *Paracalanus parvus* (CLAUS), minor form, female, lateral side. ×40.
Figs. 6A & B. *Oithona nana* GIESBRECHT. A, Male, dorsal side. ×40; B, Female, dorsal side. ×40.

PLATE XVII

Figs. 1A & B. *Oithona rigida* GIESBRECHT. A, Female. ×40; B, Male. ×40.
Figs. 2A & B. *Oithona similis* CLAUS. A, Female. ×40; B, Male. ×40.
Fig. 3. *Oithona decipiens* FARRAN, female. ×40.
Figs. 4A & B. *Euterpe acutifrons* DANA. A, Male. ×40; B, Female. ×40.
Fig. 5. *Microsetella rosea* DANA, male (above) and female (below). ×40.
Fig. 6. *Oncaea venusta* PHILIPPI, female. ×40.
Fig. 7. *Corycaeus speciosus* DANA, male. ×40.
Fig. 8. *Oncaea media* GIESBRECHT, female, dorsal and lateral sides. ×40.
Fig. 9. *Limnocaea genuina* KOKUBO female. ×40.

PLATE XVIII

Fig. 1. *Paracalanus parvus* (CLAUS), major form, female, lateral side. ×40.
Fig. 2. *Corycaeus consinnus* DANA, female. ×40.
Fig. 3. *Corycaeus flaccus* GIESBRECHT, female. ×40.
Fig. 4. *Oithona plumifera* BAIRD, female. ×40.
Fig. 5. *Oithona robusta* GIESBRECHT. ×40.
Fig. 6. *Calanus pauper* (GIESBRECHT), female. ×20.
Fig. 7. *Acrocalanus gibber* GIESBRECHT, female. ×20.
Fig. 8. *Setella gracilis* DANA, female. ×40.

PLATE XIX

Fig. 1. *Stegosoma magnum* LANGERHANS. ×40.
Fig. 2. *Oikopleura dioica* FOL. ×40.

Fig. 3. *Oikopleura longicauda* Vogt. ×40.
Fig. 4. *Oikopleura fusiformis* Fol. ×40.
Fig. 5. *Oikopleura rufescens* Fol. ×40.
Fig. 6. *Oikopleura cophocerca* Gegenbaur. ×40.

Plate XX

Fig. 1. *Fritillaria tenella* Lohmann. ×40.
Fig. 2. *Fritillaria borealis* f. *sargassi* (Lohmann). ×40.
Fig. 3. *Fritillaria haplostoma* Fol. ×40.
Fig. 4. *Fritillaria venusta* Lohmann. ×40.
Fig. 5. *Fritillaria formica* f. *digitata* Lohmann & Bückmann. ×40.

Plate XXI

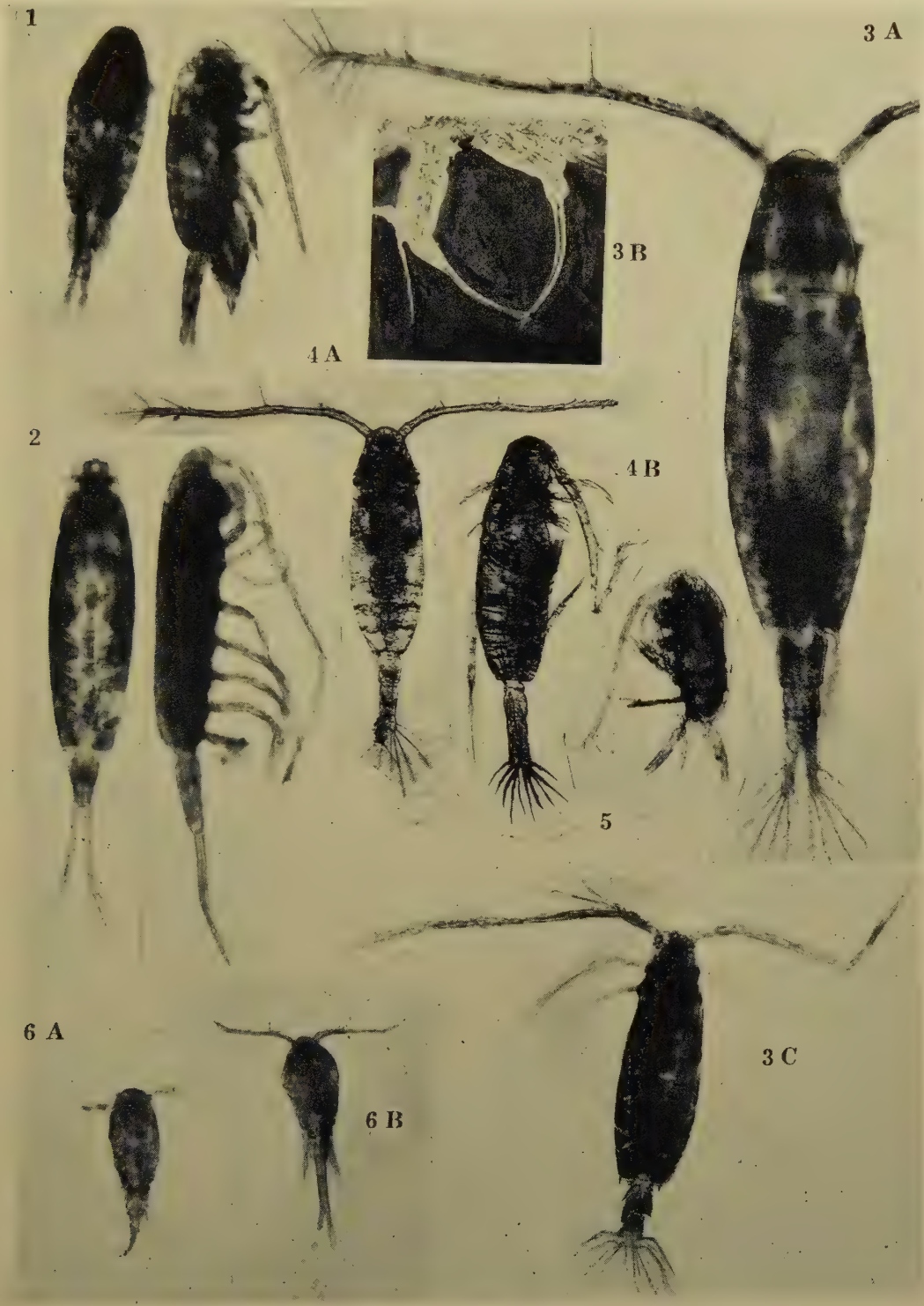
Fig. 1. *Sagitta robusta* Doncaster. ×12.
Fig. 2. *Sagitta bipunctata* Krohn. ×12.
Fig. 3. *Sagitta serratodentata* Krohn. ×12.
Fig. 4. *Sagitta enflata* Grassi. ×6.
Fig. 5. *Sagitta delicata* Tokioka. ×24.
Fig. 6. *Sagitta minima* Grassi. ×24.
Fig. 7. *Sagitta crassa* f. *naikaiensis* Tokioka. ×24.
Fig. 8. *Sagitta crassa* Tokioka. ×12.
Fig. 9. *Sagitta regularis* Aida. ×12.
Fig. 10. *Sagitta neglecta* Aida. ×12.
Fig. 11. *Evadne tergestina* Claus. ×24.
Fig. 12. *Podon* sp. ×24.
Fig. 13. *Penilia schmackeri* Richard. ×24.
Fig. 14. *Evadne nordmanni* Loven. ×24.

Plate XXII

Fig. 1. *Skeletonema costatum* Cleve. ×240.
Fig. 2. *Leptocylindrus danicus* Cleve. ×240.
Fig. 3. *Nitzschia seriata* Cleve. ×240.
Fig. 4. *Thalassionema Nitzschioides* Grunow. ×240.
Fig. 5. *Thalassiothrix Frauenfeldii* Grunow. ×240.
Fig. 6. *Bacteriastrum hyalinum* Lauder. ×240.
Fig. 7. *Ditylium Brightwellii* Grunow. ×240.
Fig. 8. *Dactyliosolen antarcticus* Castracane. ×240.
Fig. 9. *Eucampia Zoodiacus* Ehrenberg. ×240.
Fig. 10. *Rhizosolenia setigera* Brightwell. ×240.
Fig. 11. *Biddulphia sinensis* Greville. ×120.

PLATE XXIII

Fig. 1. *Chaetoceros socialis* LAUDER. ×240.
Fig. 2. *Chaetoceros decipiens* CLEVE. ×240.
Fig. 3. *Chaetoceros distans* CLEVE. ×240.
Fig. 4. *Chaetoceros didymus* var. *protuberans* EHRENBERG. ×240.
Fig. 5. *Chaetoceros debilis* CLEVE. ×240.
Fig. 6. *Chaetoceros laciniosus* SCHÜTT. ×240.
Fig. 7. *Chaetoceros curvisetus* CLEVE. ×240.
Fig. 8. *Chaetoceros compressus* LAUDER. ×240.
Fig. 9. *Chaetoceros affinis* LAUDER. ×240.
Fig. 10. *Chaetoceros Van Heurcki* GRAN. ×480.



I. Yamazi: Plankton Investigation in Inlet Waters, XIX.

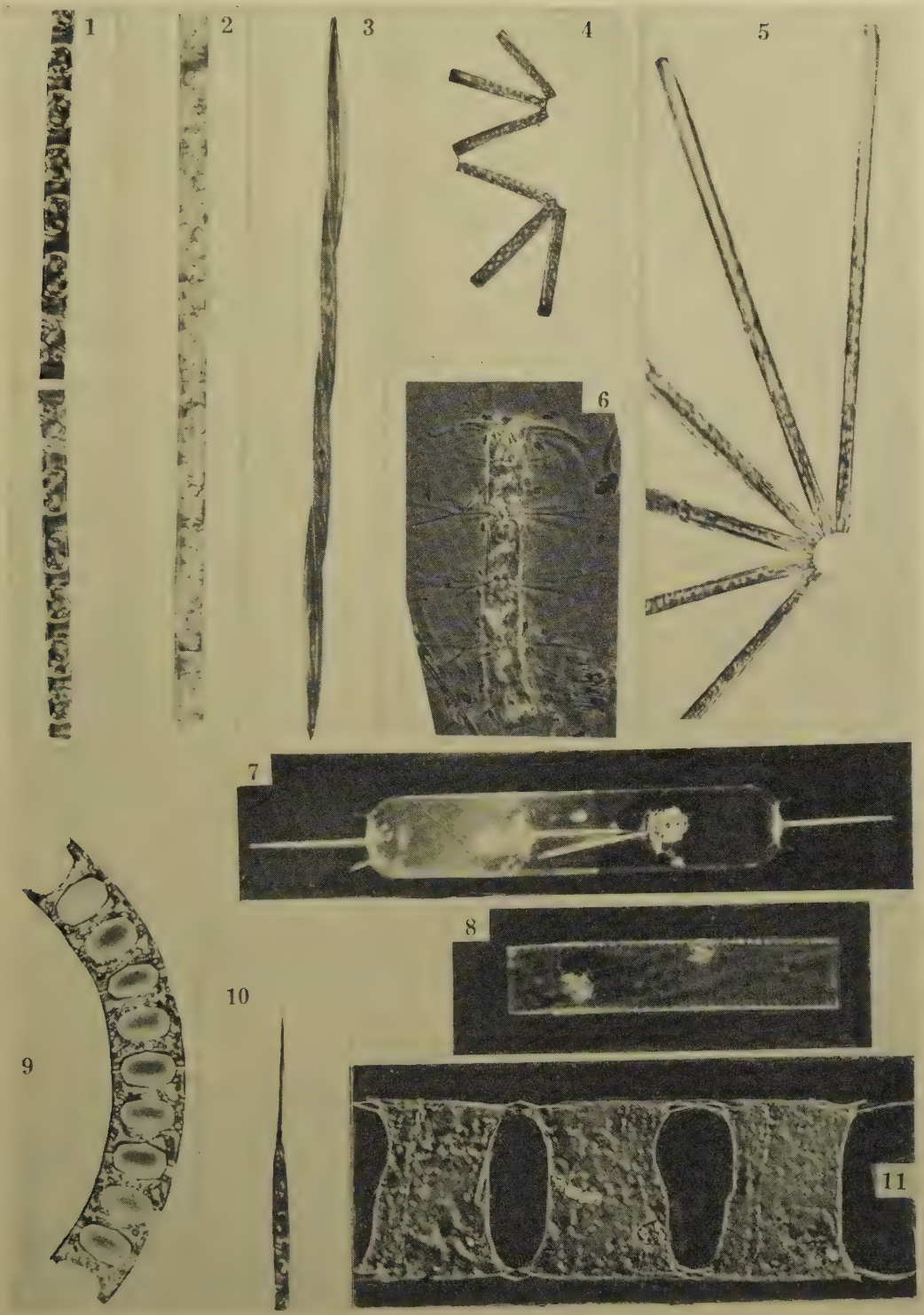
I. Yamazi: Plankton Investigation in Inlet Waters, XIX.

I. Yamazi: Plankton Investigation in Inlet Waters, XIX.

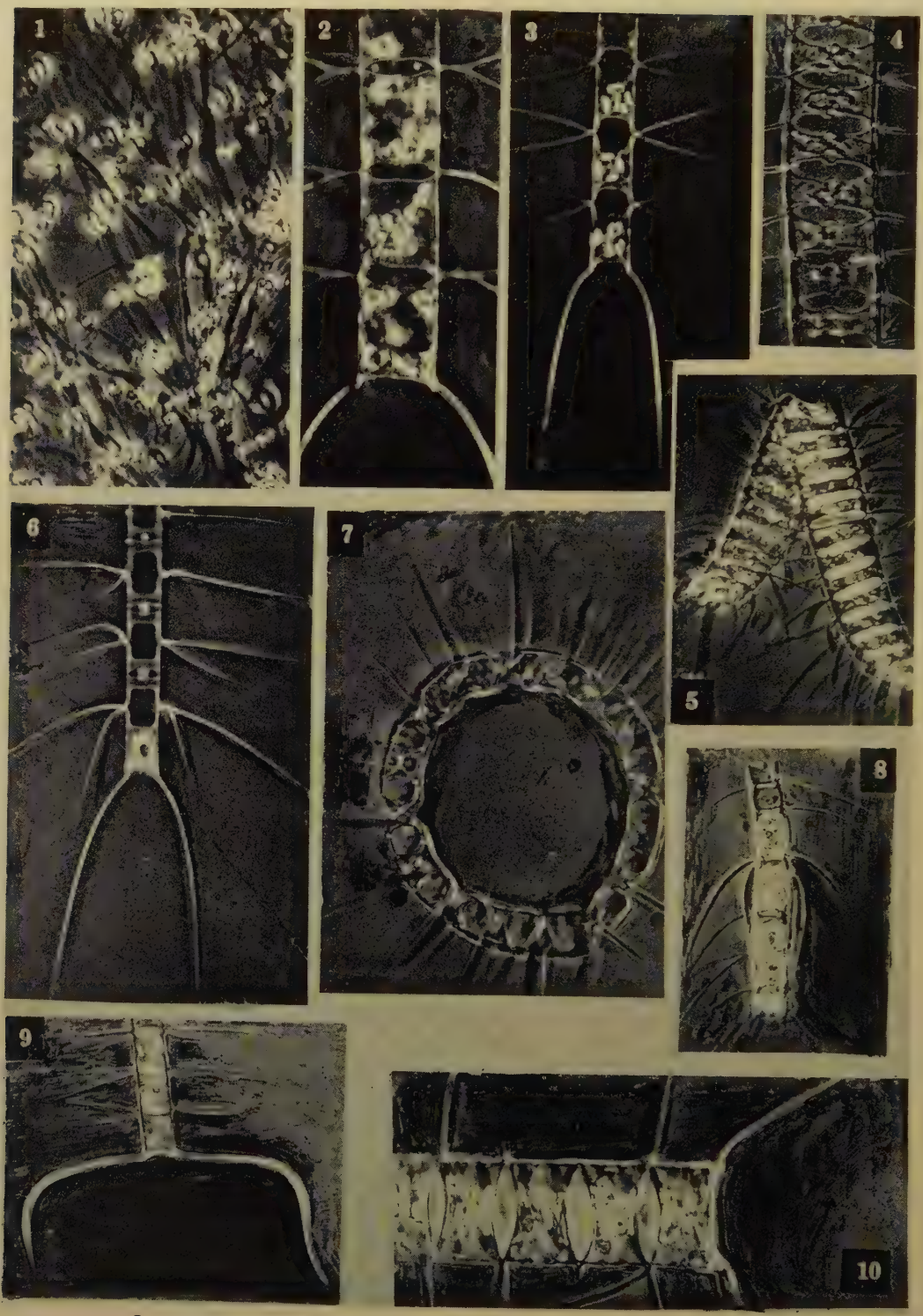
I. Yamazi: Plankton Investigation in Inlet Waters, XIX.

I. YAMAZI: PLANKTON INVESTIGATION IN INLET WATERS, XIX.

I. YAMAZI: PLANKTON INVESTIGATION IN INLET WATERS, XIX.



I. YAMAZI: PLANKTON INVESTIGATION IN INLET WATERS, XIX.



I. YAMAZI: PLANKTON INVESTIGATION IN INLET WATERS, XIX.

ON CHAETOGNATHS AND APPENDICULARIANS COLLECTED IN THE CENTRAL PART OF THE INDIAN OCEAN[1]

TAKASI TOKIOKA
Seto Marine Biological Laboratory, Sirahama

With a Chart and 2 Tables

Chaetognaths and appendicularians were selected out of 26 plankton samples collected[2] by the Syunkotu-maru, a training ship of the Simonoseki College of Fisheries, at 19 stations in the central part of the Indian Ocean, south-west to the Maldive Islands, during the period from Dec. 11, 1954 to Jan. 16, 1955 and offered to me for the identification by courtesy of Mr. S. TSURUTA of the Simonoseki College of Fisheries, to whom I express here my hearty thanks for his kindness. The situation of respective stations and the date of each sampling are indicated at the end of this article.

I. Chaetognaths

The material comprises the following 13 species. The detail of the occurrence is shown in Table 1.

	Species	Number of individuals	Percentage
1.	*Sagitta hexaptera*	58	2
2.	*Sagitta lyra*	15	1
3.	*Sagitta enflata*	579	22
4.	*Sagitta robusta*	30	1
5.	*Sagitta ferox*	19	1
6.	*Sagitta bedoti*	381	14
7.	*Sagitta serratodentata pacifica*	766	29
8.	*Sagitta regularis*	267	10
9.	*Sagitta bedfordii*	39	1
10.	*Sagitta minima*	216	8
11.	*Pterosagitta draco*	133	5

1) Contributions from the Seto Marine Biological Laboratory, No. 276.

2) KITAHARA's quantitative plankton net was hauled vertically at the speed of 50 cm per second. This is a modified HENSEN's net reduced in a smaller size, 25 cm in diameter of the mouth and 100 cm in length, and stretched with sieve silk, GG 68.

12. *Krohnitta subtilis*	40	2
13. *Krohnitta pacifica*	48	2
14. Damaged individuals or juv.	44	2
	2635	

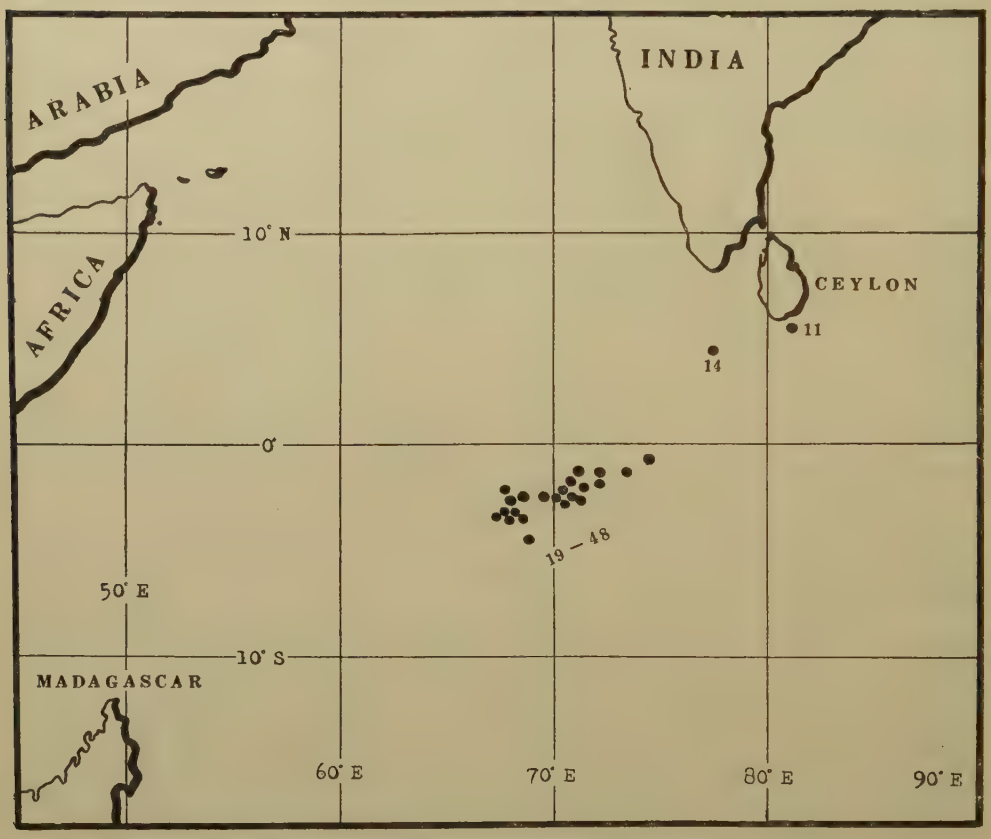


Chart 1. Map showing stations of sampling.

Sag. serratodentata pacifica and *Sag. enflata* are the dominant species and followed by *Sag. bedoti* and *Sag. regularis*. *Pterosag. draco* occurs frequently, but rather in a small number. *Sag. minima* occurs less frequently than *Pterosag. draco*, but its population is denser than that of the latter, when it is met with.

The surveyed area is located near, very slightly north of, the Area I of the "Sea lark" Expedition[1] in 1905. But, the difference found between the chaetognath faunas clarified by that expedition and the present survey seems to be rather remark-

1) BURFIELD, S. T. (1926): The Percy Sladen Trust Expedition to the Indian Ocean in 1905. No. V. The Chaetognatha of the "Sea lark" Expedition. Trans. Linn. Soc. London, Zool. Vol. XIX, Part 1.

able: *Sag. bedoti* occurred much oftener in the present material than in the "Sea lark" material and *Sag. minima* was found in a considerable quantity in the former, although it was quite absent in the latter. Comparing the present results with those of the expedition in May-June 1954 in the waters around the Marshall Islands[1] in the Pacific, the relative abundance of *Sag. serratodentata pacifica*, *Sag. bedoti*, *Sag. regularis* and *Sag. minima* and the scarcity of *Sag. bipunctata* in the central part of the Indian Ocean seem to be very impressive.

II. Appendicularians

The following 23 species were found in the material.

	Species	Number of Individuals	Percentage
1.	*Oikopleura longicauda*	371	47
2.	*Oikopleura fusiformis*	91	12
3.	*Oikopleura fusiformis* f. *cornutogastra*	1	—
4.	*Oikopleura intermedia*	7	1
5.	*Oikopleura gracilis*	4	1
6.	*Oikopleura graciloides*	1	—
7.	*Oikopleura dioica*	6	1
8.	*Oikopleura rufescens*	66	8
9.	*Oikopleura parva*	11	1
10.	*Oikopleura cophocerca*	34	4
11.	*Oikopleura albicans*	16	2
12.	*Oikopleura* spp. (damaged)	65	8
13.	*Megalocercus huxleyi*	3	—
14.	*Stegosoma magnum*	42	5
15.	*Pelagopleura verticalis*	5	1
16.	*Fritillaria haplostoma*	2	—
17.	*Fritillaria formica* f. *digitata*	11	1
18.	*Fritillaria fraudax*	1	—
19.	*Fritillaria gracilis*	2	—
20.	*Fritillaria pellucida*	6	1
21.	*Fritillaria borealis* f. *sargassi* (large individual)	4	1
21a.	„ „ (small individual)	28	4
22.	*Fritillaria borealis* f. *intermedia*	1	—

1) Tokioka, T. (1955): On some plankton animals collected by the Syunkotu-maru in May-June 1954. I Chaetognatha. Publ. Seto Mar. Biol. Lab., IV (2-3).

23. *Fritillaria megachile*	2	—
24. *Fritillaria* spp. (damaged)	4	1
25. *Appendicularia sicula*	4	1
	788	

Oik. longicauda is the dominant-most species of all and followed by *Oik. fusiformis*. *Oik. rufescens* occurs also frequently, while *Oik. cophocerca* and *Steg. magnum* are found less frequently and only in a small amount. The remarkable increase of the percentage of *Oik. fusiformis* and the decrease of that of *Oik. fusiformis* f. *cornutogastra* in the Indian Ocean are noticeable, when the present results are compared with those of the survey in the Arafura Sea. Both *Oik. dioica* and *App. sicula* are decreased considerably in the central part of the Indian Ocean. The detail of the occurrence of respective species may be understood in Table 2.

Station Number	Situation Latitude	Longitude	Date
11	5°37′ N	81°07′ E	1954 Dec. 11
19	0°43′ S	74°36.5′ E	15
22	1°07.8′ S	71°15′ E	18
23	1°46′ S	71°01′ E	19
24	2°41′ S	70°35′ E	20
25	2°15′ S	70°31′ E	21
33	2°11.5′ S	67°55.2′ E	1955 Jan. 6
34	2°26′ S	68°33′ E	7
35	3°02′ S	68°10′ E	8
36	2°28′ S	68°01′ E	9
37	3°19′ S	68°19′ E	10
38	4°35′ S	68°58′ E	11
39	3°17′ S	68°00’ E	12
40	3°10′ S	67°59′ E	13
41	3°17′ S	67°43′ E	14
43	—	—	15
44	—	—	15
45	2°31′ S	70°18.5′ E	15
47	2°02′ S	71°33′ E	16

Table 1. Detail of the occurrence of chaetognaths.

F. O.……Frequency of occurrence, M.N./H.……Mean number of individuals per haul.

Station Number	11		19	22		23	24		25	33		34		35	36	37		38	39	40		41	43	44	45	47	F. O.	M. N. / H.
Haul Distance	0-100 m	?	0-100	0-100	0-500	0-100	0-100	?	0-100	0-100	0-100	0-100	0-100	0-200	0-100	0-100	0-200	0-100	0-100	Sur.	0-100	0-200	0-100	0-100	0-100	0 200		
Sag. hexaptera					6	2			1	4		2	2				4	3	1	6	2	3	5	1	9	7	16/26	3.6
Sag. lyra							1					4					3	1			1		3	2			7	2.1
Sag. enflata	1	1	4	15	35	25	21	5	45	43	46	51	3	24	10	8	17	22	33	7	23	32	12	64	18	14	26	22.3
Sag. robusta				2	4	1	2			5		2		1	6	1		1		2			1	1		1	14	2.1
Sag. ferox	1		1		2						1		1	2					4	1	1		3	2			11	1.7
Sag. bedoti		1	4	6	15	27	10		18	43	14	26	9	9			4	6	8		9	4	31	74	45	18	21	18.1
Sag. serratodentata pacifica	10	3	12	13	91	41	10	5	27	36	73	90	9	54	8	7	43	13	17	5	18	32	32	45	40	32	26	29.5
Sag. regularis	5	3	1		5	6	7	1	10	16	2	6	2	2	66	1	5	13	10	12	12	13	19	22	25	3	25	10.7
Sag. bedfordii				2			1		5		2				1			14			1	5		1	5	2	11	3.5
Sag. minima							1			49	24	27	6	18		5	9	8	15		14	2	25	12	1		15	14.4
Sag. spp.				2	4	1	4			5	1	2	2	1		14		1	2			1		3		1	15	2.9
Pserosag. draco	5		2	6	23	3	4		5	10	4	10		5			5	9	2		1	2	12	9	6	10	20	6.7
Ktta. subtilis					3	1	1		1	2		3	1	3		1	7	3	1		3	3		5		2	16	2.5
Ktta. pacifica				2		1	3	1	4	9	5	8				1	1	1		1	1	2		7	1		16	3.0
Total	22	8	24	48	188	108	65	12	116	222	172	231	35	119	91	38	98	95	93	34	86	99	143	248	150	90		

Table 2. Detail of the occurrence of appendicularians.

F. O.……Frequency of occurrence, M.N./H.……Mean number of individuals per haul.

Station Number	11		19	22		23	24		25	33		34		35	36	37		38	39	40		41	43	44	45	47	F. O.	M. N. / H.
Haul Distance	0-100 m	?	0-100	0-100	0 500	0 100	0 100	?	0 100	0-100	0-100	0-100	0 100	0-200	0 100	0 100	0-200	0-100	0 100	Sur.	0-100	0 200	0-100	0-100	0-100	0 200		
Oik. longicauda	1	1	36	8	7	12	3	15	3	3	63	8	2	17	3	2	19	9	15	43	11	32	10	18	20	10	26/26	14.3
Oik. fusiformis			5	3		7	2	10	2	2	5	3		3	1	1	4	3	3		7	11	1	8	9	1	21	4.3
Oik. fusiformis f. *cornutogastra*																						1					1	1
Oik. intermedia																2	5										2	3.5
Oik. gracilis												2					2										2	2
Oik. graciloides																								1			1	1
Oik. dioica																1	1	3		1							4	1.5
Oik. rufescens			5		3	3	2	13	1	3	14		1	2		2	3	1	1	3		3	1	1	4		19	3.5
Oik. parva								1						1							3	1			2	3	6	1.8
Oik. cophocerca		1	1				2	1		3	4			3		1	3		1		4	3		1	4	2	15	2.3
Oik. albicans					2									4		1	5					2			1	1	7	2.3
Oik. spp.	1		1	8	6		2	4	2	4	2	1		5		5	1		5	2		4		5	4	3	19	3.4
Megal. huxleyi								1	1								1										3	1
Steg. magnum				1	5	1	5	5	5			1		2		6	1		2	2	1	1		2		2	16	2.6
Pelag. verticalis														1		2	1					1					4	1.3
Frit. haplostoma		1																						1			2	1
Frit. formica f. *digitata*								1				2		2			1				1	2			2		7	1.6
Frit. fraudax					1																						1	1
Frit. gracilis																										2	1	2
Frit. pellucida										1	1				1		2					1					5	1.2
Frit. borealis f. *sargassi* large ind.									1												1					2	3	1.3
Frit. borealis f. *sargassi* small ind.		1		4	14	2	1													1		1		1		3	9	3.1
Frit. borealis f. *intermedia*																								1			1	1
Frut. megachile					1									1													2	1
Frit. spp.					2										1	1											3	1.3
App. sicula																1			1		1	1					4	1
Total	2	4	48	24	41	25	17	51	15	16	89	17	3	41	6	25	49	16	28	52	29	64	12	39	46	29		

ON CHAETOGNATHS AND APPENDICULARIANS COLLECTED BY MR. Z. SAGARA IN THE ARAFURA SEA IN MAY–AUGUST 1955[1)]

TAKASI TOKIOKA
Seto Marine Biological Laboratory, Sirahama

With a Chart and 2 Tables

By courtesy of Mr. Z. SAGARA of the Tôkai Regional Fisheries Research Laboratory, a chance was bestowed fortunately on me to examine fifty-five plankton samples collected by him in the Arafura Sea during his oceanographical observation in the period from the end of May to the begining of August 1955. These samples were hauled by a modified HENSEN's net in miniature, 10 cm in diameter of the mouth, 25 cm in the maximum diameter, 90 cm in length and stretched with MÜLLER's gauze No. 13 (ca. 130 meshes per square inch), from the bottom to the surface at stations shown in Chart 1. The situation of stations, date and time of each sampling and some other data concerning the water of the surveyed area are given at the end of this article, where the haul distance does not mean the depth at respective stations, because the rope may very often be stretched obliquely.

Of these samples, chaetognaths and appendicularians were selected out and identified by myself, while other plankton organisms were submitted to respective specialists for their close examination. In the following, the results of my examination on the two animal groups are given in the form of tables, with some brief notes. Before going further I wish to express my hearty thanks to Mr. Z. SAGARA for his kindness.

I. Chaetognaths

Only nine species were found in the following proportion. Their occurrence is shown in detail in Table 1.

Species	Number of Individuals	Percentage
1. *Sagitta enflata*	440	34
2. *Sagitta bipunctata*	1	
3. *Sagitta robusta*	42	3
4. *Sagitta bedoti*	161	13

1) Contributions from the Seto Marine Biological Laboratory, No. 277.

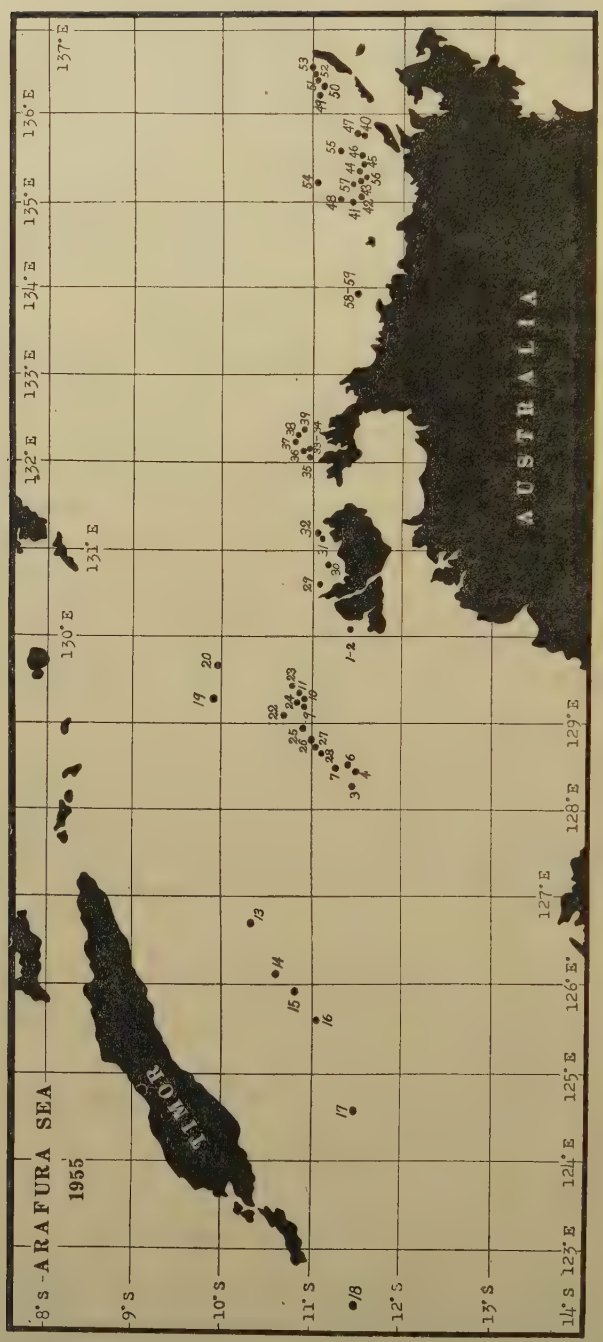


Chart 1. Map showing stations of sampling.

5.	*Sagitta serratodentata pacifica*	6	
6.	*Sagitta neglecta*	46	4
7.	*Sagitta regularis*	9	1
8.	*Pterosagitta draco*	1	
9.	*Krohnitta pacifica*	181	14
10.	Damaged individuals or juv.	374	30
		1261	

Sag. enflata is the commonest species and is followed by *Sag. bedoti* and *Ktta. pacifica*. The absence of *Sag. hexaptera* and the rareness of *Sag. serratodentata* are considered to be due to the shallowness of the surveyed area where the water was considered, in the period of observation, as being the same as that of the surface layer of the open and deep ocean and quite free from any water masses up-welled from the depth. The universal occurrence of *Sag. bedoti* is a characteristic in warm coastal waters of the Indian Ocean and the Malay Archipelagoes, and that of *Ktta. pacifica* and the scarcity of *Pterosag. draco* were observed also during the survey made by Mr. S. WADA in 1938.[1] Many juvenile individuals, of *Ktta. pacifica* were found in the present material. The water at Stations 13–18 off the southern coast of Timor was clearly much more oceanic than at other stations and samples hauled at these stations contained only a few number of chaetognaths, including no individual of *Sag. bedoti*.

II. Appendicularians

The following 19 species were detected in the material, the detail of the occurrence of respective species is given in Table 2.

	Species	Number of Individuals	Percentage
1.	*Oikopleura longicauda*	1714	52
2.	*Oikopleura fusiformis*	107	3
3.	*Oikopleura fusiformis* f. *cornutogastra*	326	10
4.	*Oikopleura intermedia*	13	
5.	*Oikopleura dioica*	68	2
6.	*Oikopleura rufescens*	383	12
7.	*Oikopleura parva*	1	
8.	*Oikopleura cophocerca*	30	1
9.	*Oikopleura* spp. (damaged)	84	3
10.	*Megalocercus huxleyi*	6	
11.	*Stegosoma magnum*	5	

1) TOKIOKA, T. (1942): Systematic studies of the plankton organisms occurring in Iwayama Bay, Palao, III. Chaetognaths of the bay and the adjacent waters. Palao Trop. Biol. St. Stud., II (3).

12.	*Fritillaria haplostoma*	32	1
13.	*Fritillaria abjornseni*	3	
14.	*Fritillaria arafoera*	1	
15.	*Fritillaria formica* f. *digitata*	4	
16.	*Fritillaria pellucida*	2	
17.	*Fritillaria borealis* f. *sargassi* (large individual)	5	
17a.	„ „ (small individual)	374	11
18.	*Fritillaria* spp. (damaged)	2	
19.	*Tectillaria fertilis*	1	
20.	*Appendicularia sicula*	155	5
21.	*Kowalevskaia tenuis*	1	
		3317	

Oik. longicauda is the dominant-most species of all and *Oik. fusiformis* f. *cornutogastra*, *Oik. rufescens* and *Frit. borealis* f. *sargassi* (small individual) follow it. *App. sicula* occurs commonly, but not in abundance. *Oik. fusiformis*, *Oik. dioica* and *Frit. haplostoma* occur less frequently and much sparsely. *Oik. cophocerca* was confined in the present survey to the area west to 129°14′E. The number of species was more numerous at Sts. 13–18 than at others. Rather universal occurrence of *Oik. dioica*, though in a small number, seems to show distinctly that the water of the surveyed area is considerably of a neritic nature.

Station Number	Situation	Date	Time	Haul Distance	Surface Temp.	Bottom Temp.	Transparency	Water Colour
1	11°25′S 130°04′E	May 29	12h 10′	20.5m	29.0C	28.4C	2.8m	8
2	11°25′S 130°04′E	30	12h	20.0	29.2	28.4	6.0	9
3	11°26′S 128°16′E	June 2	14h 20′	40.0	29.2	28.5	10.0	7
4	11°28′S 128°26′E	3	8h 5′	33.0	28.4	28.6	11.0	7
6	11°25′S 128°29′E	3	13h 15′	36.0	28.8	28.8	14.0	7
7	11°18′S 128°28′E	3	15h 30′	37.0	28.8	28.4	15.0	7
9	10°58′S 129°08′E	4	8h 15′	35.0	28.6	28.5	12.0	8
10	10°58′S 129°12′E	4	12h	35.0	28.6	28.6	10.0	8
11	10°56′S 129°14′E	4	16h 5′	33.0	28.5	28.4	14.0	8
13	10°21′S 126°40′E	14	7h 45′	33.0	28.2	28.3	33.0	3
14	10°39′S 126°04′E	15	9h 20′	26.0	27.9	27.9	20.0	4

Station Number	Situation	Date	Time	Haul Distance	Surface Temp.	Bottom Temp.	Transp-arency	Water Colour
15	10°47′S 125°51′E	June 16	8h 3′	27.0m	27.9C	27.9C	20.0m	4
16	11°05′S 125°34′E	16	16h	25.0	28.2	28.2	25.0	3
17	11°26′S 124°39.5′E	17	8h 10′	30.0	27.8	27.9	28.0	4
18	11°32.5′S 123°35′E	18	9h 30′	30.0	28.0	28.0	30.0	4
19	9°53′S 129°15′E	26	9h	11.0	27.6	27.6	11.0	4
20	9°54.5′S 129°33.5′E	26	13h	26.0	27.3	27.2	20.0	4
22	10°41′S 129°03.5′E	27	7h 32′	40.0	27.4	27.4	11.0	4
23	10°41.5′S 129°16.5′E	27	17h	38.0	27.4	27.4	10.0	5
24	10°47′S 129°10′E	28	7h 55′	35.0	27.5	27.4	12.0	5
25	10°53′S 128°51′E	28	15h 50′	35.0	27.6	27.6	17.0	4
26	11°00′S 128°44.5′E	29	8h 22′	35.0	27.7	27.7	11.0	5
27	11°02.5′S 128°44′E	29	16h 45′	36.0	27.8	27.8	15.0	5
28	11°06′S 128°25′E	July 1	7h 15′	44.0	27.2	27.2	12.0	5
29	11°04′S 130°34′E	12	14h 55′	38.0	26.2	26.2	5.0	9
30	11°11.5′S 130°45′E	13	7h 55′	22.0	26.1	26.1	2.0	11
31	11°07′S 131°09′E	13	15h	23.0	26.0	26.0	1.2	11
32	11°06.5′S 131°10′E	14	8h 10′	24.0	25.0	25.0	2.0	11
33	10°59′S 132°06.5′E	14	17h 10′	29.0	25.4	25.4	4.0	10
34	10°59′S 132°06.5′E	15	8h 30′	29.0	25.4	25.4	6.0	9
35	10°59.5′S 132°01′E	15	11h	35.0	25.6	25.5	10.0	8
36	10°55′S 132°06′E	16	10h 10′	37.0	25.6	25.6	5.0	9
37	10°50.5′S 132°10′E	16	12h 10′	44.0	25.7	25.7	5.0	8
38	10°54′S 132°13′E	16	13h 50′	35.0	25.8	25.7	5.0	7

Station Number	Situation	Date	Time	Haul Distance	Surface Temp.	Bottom Temp.	Transp-arency	Water Colour
39	10°57.5′S 132°16′E	July 16	15h 15′	23.0m	25.6C	25.6C	3.5m	9
40	11°38′S 135°48′E	18	12h	35.0				8
41	11°28.5′S 135°00′E	19	11h 50′	36.0	25.1	25.1	10.0	7
42	11°29′S 135°04′E	19	15h	36.0	25.2	25.1	10.0	8
43	11°29′S 135°11.5′E	26	10h 35′	30.0	25.3	25.3	7.0	9
44	11°29′S 135°21′E	26	13h 45′	38.0	25.6	25.6	7.0	8
45	11°32′S 135°22.5′E	26	15h 30′	38.0	25.6	25.6		7
46	11°33′S 135°33′E	27	8h	33.0	25.3	25.3	10.0	9
47	11°29.4′S 135°48.5′E	27	11h 35′	36.0	25.5	25.5	6.0	8
48	11°22′S 135°01.5′E	27	15h 10′	36.0	25.5	25.5	8.0	8
49	11°10′S 136°19′E	28	9h 50′	35.0	25.6	25.6	11.0	8
50	11°10.3′S 136°22.5′E	28	11h 50′	31.0	25.9	25.7	9.0	9
51	11°07′S 136°27′E	28	13h 30′	31.0	26.1	25.9	4.0	9
52	11°04′S 136°29.5′E	29	8h 35′	32.0	25.9	25.8	4.0	9
53	11°00′S 136°29.5′E	29	9h 52′	39.0	25.9	25.9	6.0	9
54	11°06′S 135°13.5′E	29	13h 10′	38.0	25.7	25.6	11.0	7
55	11°25.5′S 135°37.5′E	30	14h 45′	35.0	25.7	25.6	7.0	9
56	11°31′S 135°14′E	31	8h 30′	28.0	25.5	25.5	7.0	9
57	11°28.5′S 135°10′E	31	10h 35′	36.0	25.5	25.5	8.0	9
58	11°31′S 133°50.5′E	Aug. 2	13h 12′	28.0	25.2	25.1	10.0	7
59	11°31′S 133°50.5′E	3	8h 30′	30.0	25.1	25.1	8.0	8

Station Number	1	2	3	4	6	7	9	10	11	13	14	15	16	17	18	19	20	
Sag. enflata	5	2	7	10	17	11	29	16	19		2	1			2	1	5	
Sag. bipunctata																		
Sag. robusta			3	1	2	4	2		2		3							
Sag. bedoti	8	2	14	3	10	2	10	5	5								1	
Sag. serratodentata pacifica	1														1			
Sag. neglecta			5		5	4	4	6	3	1								
Sag. regularis									1		1						4	
Sag. spp.	4	4	15	6	9	12	8	6	6		3	3		1		3	5	3
Pterosag. draco										1								
Ktta. pacifica			10	2	7	5	4	8	8	2								
Total	18	8	54	22	50	38	57	41	44	4	9	4	0	1	3	4	15	5

Station Number	1	2	3	4	6	7	9	10	11	13	14	15	16	17	18	19	20	2
Oik. longicauda		3	46	106	122	65	4	3	21	16	10	11	20	39	17	32	68	1
Oik. fusiformis					1					3	11	1	21	11	13		1	
Oik. fusiformis f. *cornutogastra*		6	13	20	31	13	4	1	7	4	3					1	5	
Oik. intermedia																		
Oik. dioica		7	2	3	4	15				1								2
Oik. rufescens		25		11	6	1		1	2	7	5	2	1		4		1	
Oik. parva						1												
Oik. cophocerca				1			2	4	10	1	2				8			1
Oik. spp.			4	5	3			1	6	2	4	2	3	2	2		2	1
Megal. huxleyi						1		1			2							
Steg. magnum					1	1			1	1								
Frit. haplostoma				2		5				2	2			2			1	
Frit. abjornseni											1		1		1			
Frit. arafoera														1				
Frit. formica f. *digitata*										1	1	2						
Frit. pellucida										2								
Frit. borealis f. *sargassi* large ind.									1					2				
Frit. borealis f. *sargassi* small ind.		1	15	36	16	19	2	3	4	6	4	1	6	9	9		2	1
Frit. spp.														1				
Tect. fertilis																	1	
App. sicula		8		1				1	1		2			2	1	1		7
Kowal. tenuis				1														
Total	0	50	80	186	184	121	12	15	53	46	47	19	52	69	55	34	81	3

occurrence of chaetognaths.
/H.·····Mean number of individuals per haul.

30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	F.O.	M.N./H.
2	2	1	3	4	10	5	6	1	2	13	20	11	9	8	10	12	9	7	8	8	10	8	3	28	26	7	17		18	51/55	8.6
	1																													1	1
	1			1	1	1				2	2	1		1	1												1		8	21	2
1	5	2		2	7	2	5		2	3	3		1	1	4	2	2	2	4	7	3	10	3	10	1	2				41	3.9
										2			1														1			5	1.2
1				1			1				2		1				1		1		5	1		1						19	2.4
					1																						2			5	1.8
	1	1	6	9	5	1	2	1	4	2	12	10	2	7	19	2	3	2	4	10	14	9	8	6	11	3	10	2	6	51	7.3
																														1	1
				2	2		1			4	6	1	1	2		8	7	10	6	16	15	10	2	17	2		1		1	36	5
4	10	4	9	19	26	9	15	2	8	26	45	23	15	19	34	24	22	21	23	41	47	38	16	62	40	12	32	2	33		

occurrence of appendicularians.
./H.·····Mean number of individuals per haul.

30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	F.O.	M.N./H.
	1		1	24	20	5	8	11	57	6	45	16	17	31	40	11	16	35	28	95	61	74	125	47	44	50	95	12	23	52/55	33
								1						1	1					5						13		1		16	6.7
	1		1	5	6		4		3	1	10	3	1			2	2	6	11	26	27	12	39	7	2	3	14	5	2	42	7.8
					13																									1	13
1	2	6									3			1			1		1			2	3	1	2	8	3			20	3.4
		1	2	32	31	15	27	9	32		2	1	1	1				10	16	29	11	6	22	21	1			4	33	36	10.6
																														1	1
																														9	3.3
2				1	5	1	1	1			2				3		1			1	1		8	1	1	1	3	1		35	2.4
																							1						1	5	1.2
											1																			5	1
																		1	14										1	11	2.9
																														3	1
																														1	1
																														3	1.3
																														1	2
																														3	1.7
				3	2		1	1	1	3	8	8	1	3	17	1		8	8	20	17	4	4	5	4	18	14			44	8.5
																														2	1
																														1	1
				1	3	3		2	1		6	1	6	3	6	2	1		7	13	5	5	2			34	2			32	4.8
																														1	1
3	4	7	4	66	80	24	41	25	94	10	77	29	26	40	67	16	21	60	85	189	122	103	204	82	54	127	131	23	60		

OBSERVATIONS ON THE SPAWNING HABITS OF SOME OF THE JAPANESE OPISTHOBRANCHIA (II)[1]

KIKUTARÔ BABA, IWAO HAMATANI and KEIJIRÔ HISAI
Biological Laboratory, Osaka University of
Liberal Arts and Education

With Plates XXIV–XXVI and 3 Text-figures

5. *Goniodoris castanea* ALDER & HANCOCK

(Pl. XXIV, Figs. 1*a*–1*b*)

Reference to the species: BABA 1955, pp. 17–18, pl. 8, fig. 19, text-fig. 22.

Unlike those of *G. glabra*, the spawns here obtained from Seto and Kada, Kii Province, during May and June, are entirely colourless, and each consists of a long broad ribbon which is attached along its edge and wound in a loose spiral. The diameter of the whole spiral in surface view is about 10 mm. The capsules within the ribbon contain a single egg each.

6. *Glossodoris pallescens* (BERGH)

(Text-fig. 1; Pl. XXIV, Fig. 2)

Reference to the species: BABA 1949, p. 50, pl. 17, fig. 60, text-fig. 53.

The spawning of this species appears to be most active from July to early August. In Toyama Bay and at Sado Island of the Japan Sea side, the full-grown animals come together during this period in enormous numbers, copulate, and lay eggs in rocky beds or in shaded caves below the water. Here the egg mass is distinct in being laid flat on the substratum. It consists of a long and ashy white ribbon, coiled tightly in about 2¼ convolutions. The whole mass measures from 12 to 15 mm in diameter in surface view. A single egg is contained within each capsule. Spawning has also been observed at Tannowa, Osaka Bay, in July.

1) Contributions from the Seto Marine Biological Laboratory, No. 278.

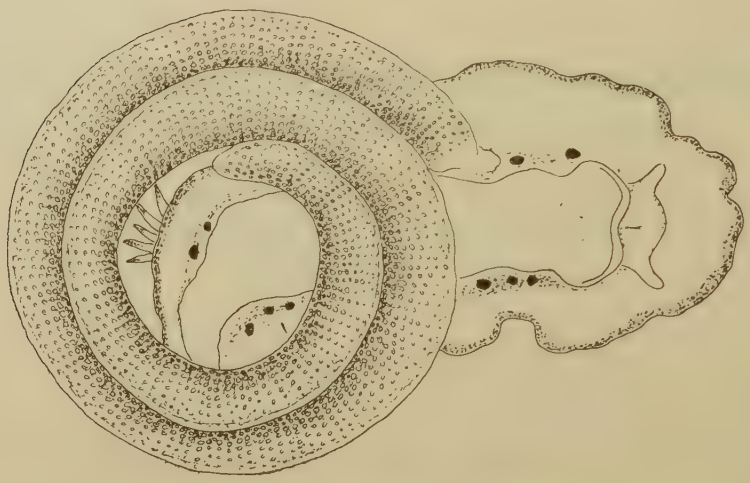


Fig. 1. *Glossodoris pallescens.*
A spawning animal from below (Kannonzaki, Toyama Bay, at 10 a.m., July 27, 1952). ×5.

7. *Glossodoris festiva* (ADAMS)

(Text-fig. 2; Pl. XXIV, Figs. 3*a*–3*c*)

Reference to the species: BABA 1949, p. 51, pl. 18, fig. 63, text-fig. 56.

The spawning period of this species is from May to early August. Copulation

Fig. 2. *Glossodoris festiva.*
Pairing animals from above (Seto, at 2:30 p.m., June 10, 1952). ×2.5.

was once observed at Seto in a tide pool under direct sunshine in June. In Toyama Bay this species was found congregate and spawning most actively late in July. The egg mass thus laid on the leaves of the sea-weeds or on rock is very much unlike that of *G. pallescens* in general appearance. The ribbon of the egg mass is in from 2 to 3¼ convolutions, and it is always found standing vertically along the edge. The whole egg mass is ashy white and 10–14 mm in diameter in surface view. As usual a single egg is contained within each of the capsules.

8. *Glossodoris sibogae* (Bergh)

(Pl. XXIV, Fig. 4)

Reference to the species: Baba 1949, p. 51, pl. 17, fig. 62, text-fig. 55.

During the early part of August the fully matured specimens of this species have commonly been found on the shores of Sado Island, particularly in such places as shaded caves below the water. The spawn obtained in the aquarium tank of the Sado Marine Biological Laboratory does not differ much in general shape and colouring from that of *G. festiva*. It is coiled in about 1½ convolutions. The diameter of the whole egg mass in surface view measures about 12 mm. The majority of the capsules as usual contain a single egg each.

9. *Glossodoris aureopurpurea* (Collingwood)

(Pl. XXIV, Fig. 5)

References to the species: Baba 1949, p. 50, pl. 17, fig. 61, text-fig. 54; Abe & Baba 1952, pp. 262, 265, figs. 6, 9.

A spawn of this species has been taken in Toyama Bay during the last part of July. It is formed of a long and narrow ribbon, fastened to the substratum by the inner edge, and the whole mass is in a loosely wound spiral of 3½ convolutions. The ribbon is as usual ashy white in colour.

10. *Aldisa sanguinea* (Cooper)

(Pl. XXIV, Fig. 6)

Reference to the species: Baba 1949, pp. 62–63, pl. 24, fig. 86, text-fig. 75.

Specimens of this species, deep orange yellow and kept alive in the Sugashima Marine Biological Laboratory, have laid eggs during the last half of April. The egg masses thus in hand are all of a vivid orange yellow, and take the form of a spiral coil of from 2 to 4 convolutions. The whole egg mass is 8–13 mm in diameter in surface view. A single egg is contained in each capsule.

11. *Homoiodoris japonica* Bergh

(Pl. XXIV, Figs. 7*a*–7*b*)

Reference to the species: Baba 1949, p. 66, pl. 25, figs. 91-92, text-fig. 81.

Usually associated with the orange-coloured sponge, *Reniera japonica*, this form represents one of the commonest dorids in our territory. The breeding season is from March to July, and during this period (especially during the months from April to June) the egg masses in pink or in chrome yellow are to be found in large quantities everywhere on shores in different situations, viz. in rock crevices, and on rock surface sheltered by brown algae, etc. The egg masses themselves are each in the form of a long broad ribbon which in its turn is coiled in from 1½ to 2 convolutions. The whole egg masses thus in spiral coil measure more or less than 6 cm in diameter in surface view. The capsules within the ribbon contain usually from 3–6 eggs in each.

12. *Argus speciosus* Abraham

(Pl. XXIV, Figs. 8*a*–8*b*)

Reference to the species: Baba 1949, pp. 67–68, pl. 26, fig. 96.

Specimens of this species are also common, or even abundant on shores around the Seto Marine Biological Laboratory. The spawning season studied by us there is from May to early July. As usual the egg masses are found among rocks, but they have a series of distinctions which make the recognition of the species very easy. (1) These egg masses are strikingly large and voluminous, the diameter of the individual masses in surface view being 7–8 cm. They are remarkably tinged with orange yellow. (2) The egg masses are each in the form of a long broad ribbon and the whole length of it is complicated by thick foldings. (3) As many as 7–30 eggs are contained within each of the capsules.

13. *Dendrodoris* (*Dendrodoris*) *gemmacea* (Alder & Hancock)

(Pl. XXIV, Fig. 9)

Reference to the species: Baba 1949, pp. 69–70, pl. 27, figs. 100–101.

The spawning of this species has been observed at Seto in May and early in June. The egg mass is of an ashy white colour, contains 2½ convolutions, and forms a disk about 6 cm in diameter. The majority of the capsules contain a single egg. Sometimes there are 2–3 eggs packed within one capsule.

14. *Dendrodoris* (*Doriopsilla*) *miniata* (Alder & Hancock)

(Pl. XXIV, Fig. 10)

Reference to the species: Baba 1949, p. 71, pl. 28, figs. 105–106.

The spawning of this species has been recognized at Seto during May in the field and in the aquarium. The egg mass is small (about 17 mm in diameter of the whole mass), and of a deep chrome-yellow colour. It is coiled in about 1½ convolutions. From 1 to 2 eggs are contained in each capsule.

15. *Dermatobranchus* (*Dermatobranchus*) *striatus* (van Hasselt)

(Pl. XXV, Figs. 1*a*–1*b*)

Reference to the species: Baba 1949, p. 73, pl. 29, fig. 109, text-fig. 83.

The specimens of this species have been found spawning in the aquarium of the Sugashima Marine Biological Laboratory and at Abugashima Island in Toyama Bay during the month of July. The parent animals measured about 20 mm in length. The egg mass is here in the form of a short, flat, whitish or pinkish white ribbon which is fastened flat to the substratum in a shallow curve. The length of the ribbon is about 6–8 mm. Only 1 egg is contained in each capsule.

16. *Dermatobranchus* (*Dermatobranchus*) *striatellus* Baba

(Pl. XXV, Fig. 2)

Reference to the species: Baba 1949, pp. 74–75, pl. 30, fig. 110, text-figs. 85–86.

The spawns obtained at Seto in the aquarium in June were very much unlike those in *D. striatus*. Actually they take the form of a small glass cup with a short stalk by which the whole mass is fastened to the other object. The diameter of the cup in surface view varies from 2.3 to 3 mm. The capsules are not thickly set in the egg mass. The eggs are large relative to the size of the egg mass, and slightly tinged with yellow. As before, a single egg is enclosed within each of the capsule.

17. *Melibe vexillifera* Bergh

(Pl. XXV, Figs. 3*a*–3*b*)

Reference to the species: Baba 1949, p. 93, pl. 38, fig. 136.

The breeding season of this species is from March to August. At Yuzaki in the neighbourhood of the Seto Marine Biological Laboratory, especially abundant masses of eggs are to be found almost every year among the rocks in tidal days of May and June. These egg masses are shaped roughly as in *M. leonina* (see O'DONOGHUE 1922, pp. 134–135, pl. 4, fig. 9), and measure about 25–40 mm in total size. Each of the egg masses is in the form of a long, broad, orange red to orange yellow ribbon, and is fastened to the leaves of the seaweeds or directly to the rock surface in a much twisted manner. The majority of the capsules contain 1–3 eggs in each.

18. *Cratena ornata* BABA

(Text-fig. 3A; Pl. XXV, Fig. 4)

Reference to the species: BABA 1955, pp. 27–28, pl. 14, figs. 38–39, text-figs. 42–43.

The spawning of this species has taken place in Osaka Bay and its vicinity in February, March and in June. The eggs, slightly yellowish white in colour, are laid in a sinistral coil of about 3–4 turns with a total diameter of 7–10 mm in surface view of the coil. Only 1 egg is contained in each capsule.

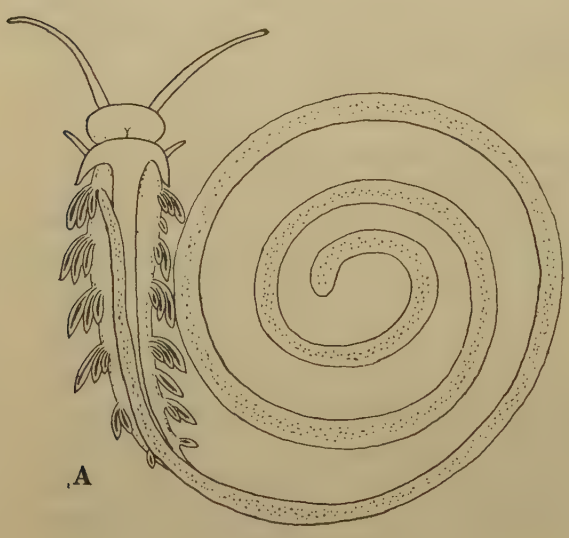


Fig. 3A. *Cratena ornata.*
A spawning animal from below (Tannowa, Osaka Bay, at 2:30 p. m., Mar. 18, 1951). ×6.

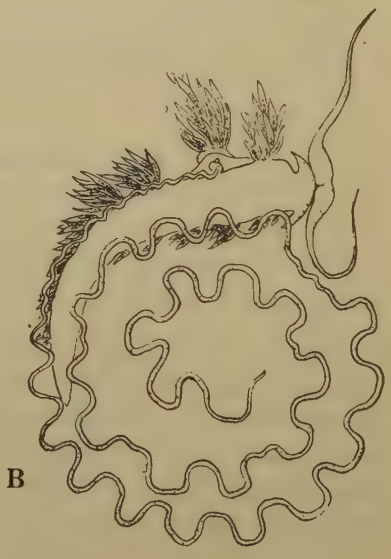


Fig. 3B. *Hervia ceylonica.*
A spawning animal from below (Tannowa, Osaka Bay, at 3 p. m., Mar. 30, 1951). ×2.

19. *Favorinus japonicus* Baba

(Pl. XXV, Figs. 5*a*–5*b*)

Reference to the species: Baba 1949, pp. 101–102, pl. 43, fig. 150, text-figs. 133–134.

Spawning in this species has taken place at Seto in June. The egg mass consists of a slender, opaque white string which is sinistrally coiled to form a circular patch measuring about 4 mm in diameter. The egg capsules are in double rows in the string. They contain a single egg each.

20. *Hervia ceylonica* Farran

(Text-fig. 3B; Pl. XXV, Figs. 6*a*–6*b*)

References to the species: Baba 1949, p. 104, text-figs. 138–139; Baba 1955, p. 34, pl. 20, figs. 54–56.

Specimens of this species sometimes come together in considerable numbers among rocks or upon sea-weeds, and lay eggs underneath stones during the months from March to July (most actively from March to May). They also spawn easily in captivity. The egg masses thus laid are slightly pinkish yellow, and form perfectly circular patches of about 25–27 mm in diameter. These are composed of a narrow cylindrical string coiled sinistrally like a spiral spring, and the entire string in its turn is thrown into a series of minute loops. The eggs are each protected by a capsule.

The spawns of *H. emurai* Baba, obtained by Mr. Y. Honma from the pool in front of the Sado Marine Biological Laboratory in May, 1954, are much like those of *H. ceylonica* in general appearance.

21. *Hervia lineata* Eliot

(Pl. XXV, Fig. 7)

Reference to the species: Baba 1949, pp. 103–104, pl. 44, figs. 152–153, text-fig. 137.

This species is found spawning in August at Wagu, Shima Province, and at Abugashima Island, Toyama Bay. The egg masses thus obtained are whitish, 3–4 mm in diameter across the masses, and consist of a narrow string which does not form complicated loops as seen in *H. ceylonica*. A single egg is contained as usual within each capsule.

22. *Aeolidiella japonica* Eliot

(Pl. XXV, Figs. 8*a*–8*c*)

Reference to the species: Baba 1949, p. 111, pl. 49, fig. 166, text-fig. 153.

A large specimen of this species, kept alive in water, has spawned twice at Seto late in June. The egg-strings are yellowish white, and are elaborately thrown into a series of triangular loops. From 2 to 4 eggs are contained in each of the capsules.

23. *Hydatina physis* (Linné)

(Pl. XXVI, Figs. 1*a*–1*c*)

The animals of this beautiful species are fairly common on shores at Seto. They become mature, copulate head to tail, and lay eggs most actively during the months of May and June. The egg masses thus laid on sandy beach and somewhat deeply inserted within it, are in the form of long, broad, ashy white ribbons, each of which in its turn is collected together in a much twisted manner. The majority of the capsules within the egg masses are packed with 7–16 eggs. The whole egg masses are about 25×40 mm in size.

24. *Aplysia* species and their allies

(Pl. XXVI, Fig. 2)

The youngest specimens of *Aplysia kurodai* (Baba) usually come ashore very early in winter. They gradually get larger, copulate in chains and lay the most abundant egg masses during the months from April to June (the actual breeding season of this species being from March to July). The egg masses in this species are from pink to yellow, and the egg-strings which form the masses are about 1 mm in thickness. A large number of eggs (15–30 or more) are crowded together within each of the capsules.

Almost everywhere on shores the voluminous egg masses of *A. sibogae* Bergh are seen usually mixed with those of *kurodai*.

A. parvula Mörch is a small-sized species which lays eggs comparatively in small masses. These latter are pink or yellow, and are formed of fine strings measuring about 0.5 mm in thickness. Only a few (2–3) eggs are contained in each of the capsules. At Seto and Sugashima of the Pacific Ocean side, this species spawns most actively from March to May, and in Toyama Bay of the Japan Sea side it is found laying until as late as the end of July.

The egg masses of *A. hirasei* (Baba) are roughly as large as those of *parvula*, but the former are easily recognized in the field by their peculiar colouring of yellowish

green. There are 2–3 eggs within each of the capsules. At Seto the spawns of this species are to be found most commonly from March to June.

The species, *Notarchus* (*Bursatella*) *leachii leachi* BLAINVILLE, var. *freeri* (GRIFFIN), has been found spawning in the field in November at Kada, and in aquarium in May at Seto (see also GRIFFIN 1912, p. 66). The egg-strings are approximately as large as those of *A. kurodai*, about 1 mm thick, faintly green when fresh, and the capsules within the strings are packed with 15–25 eggs.

25. *Pleurobranchaea novaezealandiae* CHEESEMAN

(Pl. XXVI, Figs. 3*a*–3*c*)

Reference to the species: BABA 1949, p. 38, pl. 10, fig. 34, text-figs. 31–32.

This species comes ashore very early in winter. It occurs most abundantly in the waters round Seto and some other stations, and spawns among rocks during the periods from early March to the last part of June. The egg masses are deposited in the form of long, cylindrical, ashy white tubes (see TCHANG 1936, pl. 3, fig. 11, pl. 13, figs. 1–2), apparently hollowed in the centre. The tubes themselves are in loose loops, attached along their edges, and measure from 8 to 40 cm long and about 5–10 mm thick. Within the tubes the strings of capsules are arranged round the hollowed spaces, so as to assume an indistinct, striated appearance of the whole length of the tubes. From 1 to 4 of the eggs are enclosed within one capsule.

26. *Elysia* (*Elysia*) *marginata* (PEASE)

(Pl. XXVI, Figs. 4*a*–4*b*)

Two small specimens, referable to the above species, were collected from Seto in August, 1952. The spawn obtained at that time in the aquarium is formed of a narrow string wound loosely in a spiral coil of about 6 mm in diameter in surface view. It is entirely opaque white. A single egg is within each capsule.

E. (*E.*) *abei* BABA (see BABA 1949, pl. 8, fig. 26 and BABA 1955, p. 11, text-fig. 10) is to be found abundantly on various sea-weeds growing round the Abugashima Island in Toyama Bay. The spawn of this species, laid down in captivity late in July, has assumed the same general appearance as that of *marginata*.

27. *Elysia* (*Elysia*) *atroviridis* BABA

(Pl. XXVI, Fig. 5)

Reference to the species: BABA 1955, p. 12, text-figs. 11–12.

Abundant specimens of this *Elysia* have been found attacking on *Codium contractum* in May at Sugashima. They have continued spawning in captivity during

May and June. The spawns are opaque white, 2–3 mm across the spiral coil, and a little more tightly wound than in *marginata* and in *abei*.

28. *Elysia* (*Elysia*) *halimedae* Macnae

(Pl. XXVI, Fig. 6)

Reference to the species: Macnae 1954, pp. 57–59, pl. 3, fig. 2, text-fig. 2.

A handsome specimen, possibly to be referred to the above species from South Africa, was found associated with *Halimeda cuneata* growing among rocks at Wagu, Shima Province, in the early part of August, 1951. The spawn of this captured animal is seen to be formed of a long but somewhat broad and flattened band in more or less tight spiral. It is faintly tinged with yellow.

REFERENCES

Abe, T. & Baba, K. 1952. Notes on the opisthobranch fauna of Toyama Bay, western coast of Middle Japan. Collecting and Breeding, vol. 14, no. 9 (in Japanese).

Baba, K. 1955. Opisthobranchia of Sagami Bay. Supplement. Iwanami Shoten, Tôkyô.

Griffin, L. E. 1912. The anatomy of *Aclesia freeri* new species. Philippine Journ. Sci., vol. 7, sec. D, no. 2.

Macnae, W. 1954. On four sacoglossan molluscs new to South Africa. Ann. Natal Mus., vol. 13, pt. 1.

Tchang, Si 1936. Contribution a l'étude des opisthobranches de la côte de Tsingtao. Contrib. Inst. Zool. Nat. Acad. Peiping, vol. 2, no. 2, f. 1934.

EXPLANATION OF PLATES XXIV–XXVI

Plate XXIV

Figs. 1*a*–1*b*. *Goniodoris castanea.*

1*a*. A complete egg-ribbon from side (Seto, May 10, 1952). ×4.5.

1*b*. An egg-capsule. ×110.

Fig. 2. *Glossodoris pallescens.* An egg-capsule. ×130.

Figs. 3*a*–3*c*. *Glossodoris festiva.*

3*a*. A complete egg mass from side (Seto, May 13, 1952). ×4.

3*b*. Another egg mass from side (Abugashima, Toyama Bay, July 23, 1952). ×3.

3*c*. An egg-capsule. ×130.

Fig. 4. *Glossodoris sibogae.* A complete egg mass from side (Sado, Aug. 4, 1954). ×3.

Fig. 5. *Glossodoris aureopurpurea.* A complete egg mass from above (Abugashima, Toyama Bay, July 24, 1951). ×5.

Fig. 6. *Aldisa sanguinea.* A complete egg mass from above (Sugashima, Apr. 18, 1954). ×4.

Figs. 7*a*–7*b*. *Homoiodoris japonica.*

7*a*. A complete egg mass from above (Sugashima, May 7, 1951). ×2/3.

7*b*. An egg-capsule with 3 eggs. ×90.

Figs. 8*a*–8*b*. *Argus speciosus.*

8*a*. A part of the thickly folded egg-ribbon. ×4/5.

8*b*. An egg-capsule with 10 eggs. ×50.

Fig. 9. *Dendrodoris gemmacea.* A complete egg mass from above (Seto, May 11, 1952). ×2/3.

Fig. 10. *Dendrodoris miniata.* A complete egg mass from above (Seto, May 10, 1952). ×3.5.

Plate XXV

Figs. 1*a*–1*b*. *Dermatobranchus striatus.*

1*a*. A complete egg mass from above (Sugashima, July 7, 1952). ×8.

1*b*. An egg-capsule. ×100.

Fig. 2. *Dermatobranchus striatellus.* A cup-shaped egg mass from side (Seto, Apr. 18, 1952). ×20.

Figs. 3*a*–3*b*. *Melibe vexillifera.*

3*a*. A much twisted egg mass from above (Seto, June 9, 1952). ×1.5.

3*b*. An egg-capsule with 3 eggs. ×40.

Fig. 4. *Cratena ornata*. A part of egg-string. ×15.

Figs. 5*a*–5*b*. *Favorinus japonicus*.

5*a*. A complete egg mass from below (Seto, June 22, 1951). ×14.

5*b*. A part of egg-string. ×30.

Figs. 6*a*–6*b*. *Hervia ceylonica*.

6*a*. A complete egg mass from below (Tannowa, Osaka Bay, Mar. 30, 1951). ×1.6.

6*b*. A part of egg-string. ×15.

Fig. 7. *Hervia lineata*. A complete egg mass from below (Wagu, Shima Province, Aug. 4, 1951). ×15.

Figs. 8*a*–8*c*. *Aeolidiella japonica*.

8*a*. A somewhat incomplete egg mass (Seto, June 22, 1951). ×1.5.

8*b*. A part of egg-string. ×15.

8*c*. An egg-capsule with 4 eggs. ×170.

Plate XXVI

Figs. 1*a*–1*c*. *Hydatina physis*.

1*a*. Pairing animals from above (Seto, at 10 : 30 a. m., June 8, 1952). ×1.5.

1*b*. A complete egg mass from side (Seto, June 8, 1952). ×1.

1*c*. An egg-capsule with 9 eggs. ×70.

Fig. 2. *Aplysia kurodai*. Cross section of an egg-string (Seto, May 13, 1952). ×30.

Figs. 3*a*–3*c*. *Pleurobranchaea novaezealandiae*.

3*a*. A complete egg mass from above (Seto, Apr. 1, 1953). ×1/2.

3*b*. A part of egg mass from side. ×2.5.

3*c*. An egg-capsule with 4 eggs. ×60.

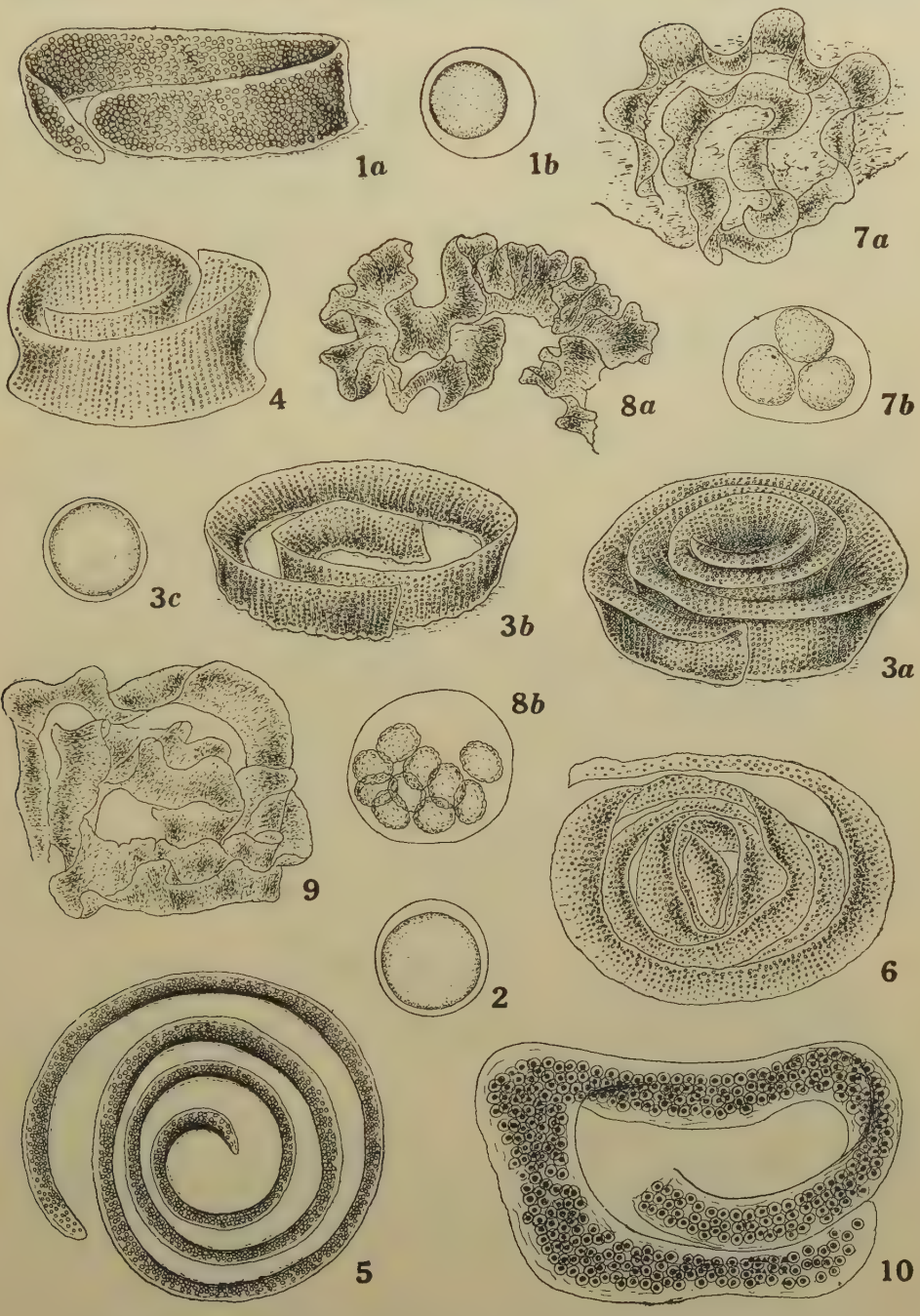
Figs. 4*a*–4*b*. *Elysia marginata*.

4*a*. A complete egg mass from above (Seto, Aug. 9, 1952). ×8.

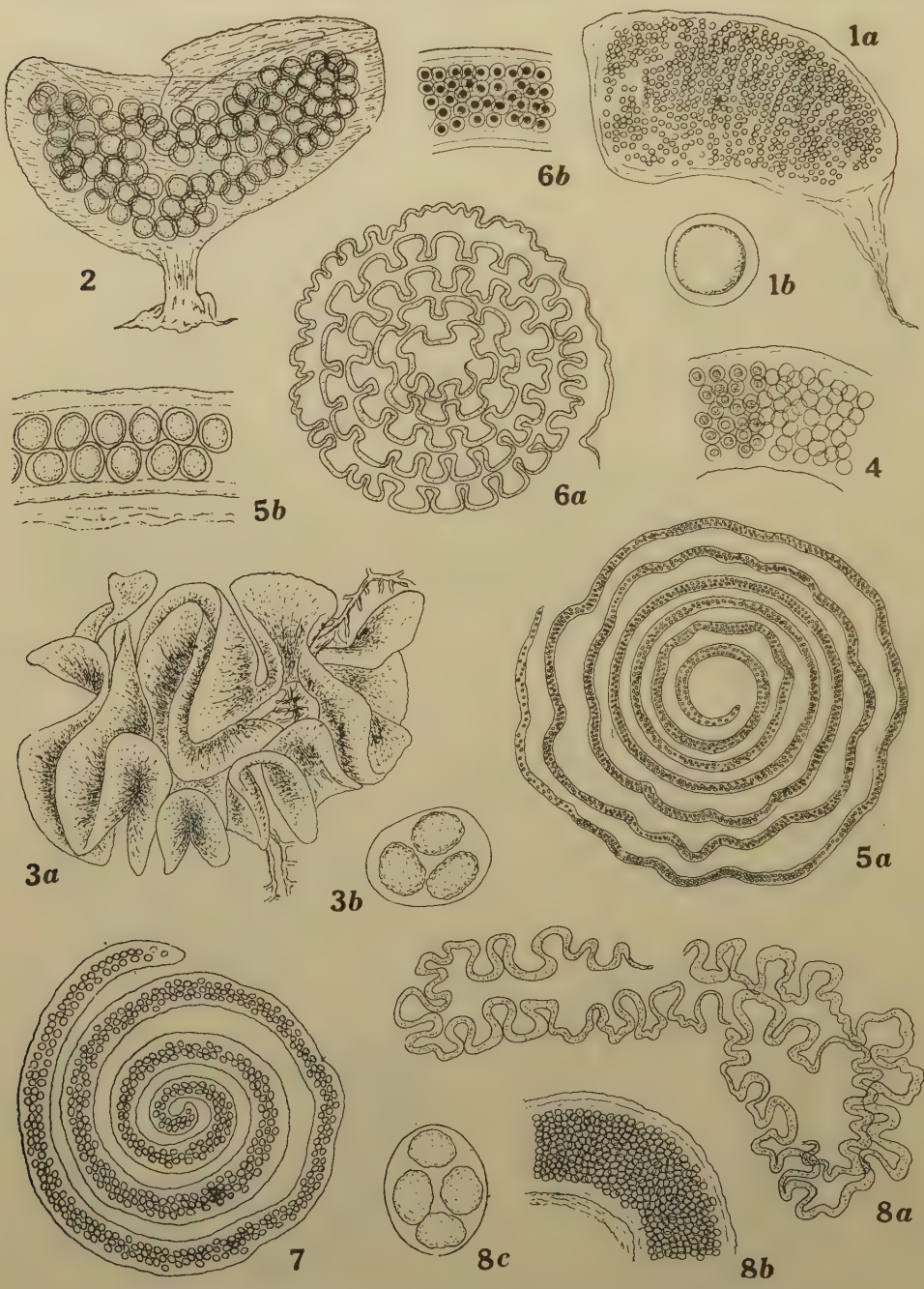
4*b*. An egg-capsule. ×70.

Fig. 5. *Elysia atroviridis*. A complete egg mass from below (?) (Sugashima, June 4, 1951). ×20.

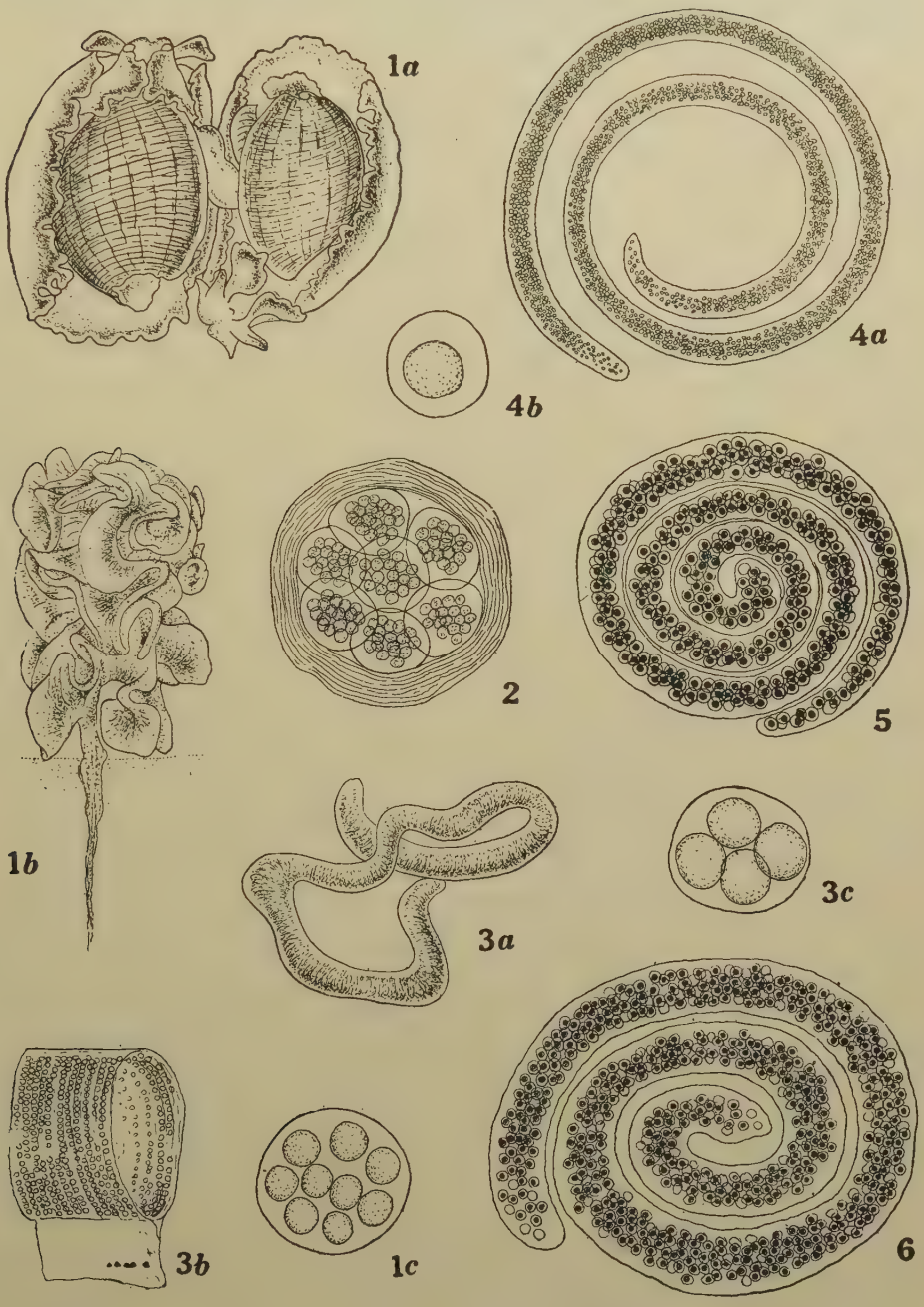
Fig. 6. *Elysia halimedae*. A complete egg mass from above (Wagu, Shima Province, Aug. 4, 1951). ×8.



K. Baba *et al.*: Spawning Habits of Japanese Opisthobranchia, II.



K. Baba *et al.*: Spawning Habits of Japanese Opisthobranchia, II.



K. Baba *et al.*: Spawning Habits of Japanese Opisthobranchia, II.

ON SOME ALCYONARIANS FROM THE WEST-PACIFIC ISLANDS (PALAU, PONAPE AND BONINS)[1]

Huzio UTINOMI
Seto Marine Biological Laboratory, Sirahama

With 9 Text-figures

The Alcyonarian fauna of the tropical West-Pacific region, covering the large area of Micronesia in a wide sense, has previouly been scarcely investigated, though a few records concerning the Alcyonacea were noted by May (1900) and Kükenthal (1903, 1905).

During my stay at Koror of the Palau Islands as a research associate of the Palao Tropical Biological Station from June 1934 to February 1935 to study the marine fauna inhabiting the coral reef, I was much impressed by the abundance of fleshy Alcyonaceans, covering extensive areas of the reef edges or seaward slopes and the marked fewness of Gorgonaceans with an only exception of a few species of *Melithaea* (=*Melitodes*) and *Junceella*. Owing to having other objects, however, my shore-collecting could not be extended to the Alcyonaria at that time. Fortunately enough, some of the unstudied materials from Micronesia, mainly collected in the Palau Islands, which may be only available as the Micronesia collection made by Japanese zoologists in the pre-war time, were kindly placed at my disposal for study.

All the material dealt with in this paper is from the following three sources. The Museum of the Zoological Institute of Kyoto University at Kyoto possesses 12 samples which were collected by Syô Takahashi, then Professor of Hiroshima Higher Normal School, at Palau Islands during a short stay between March 5–30, 1915. The Museum of the Zoological Institute of Tokyo University at Tokyo has a very few samples from Bonin (Ogasawara) Islands collected by Sadamori Hirota and Ryûtarô Sekiguchi between February 10 to April 22, 1894, and one from Ponape Island. In the Museum of the Seto Marine Biological Laboratory at Sirahama, there is a small collection, most of which were made by Toshihiko Yamanouchi in 1937 during the survey of Iwayama Bay of Koror Island, containing my own made in 1934.

To all the gentlemen in charge of the collections of these Institutions and to Dr. Shinkishi Hatai, then Director of the Palao Tropical Biological Station, I wish to express my hearty thanks.

1) Contributions from the Seto Marine Biological Laboratory, No. 279.

For the locality names used in the following text, GRESSITT's gazetteer (1954) is followed here for convenience, but only partially synonyms previously used by Japanese are also put in parentheses. The abbreviations of the sources of the material are as follows:

Z. I. K.·····Zoological Institute, Kyoto University, Kyoto.
Z. I. T.·····Zoological Institute, Tokyo University, Tokyo.
S. M. B. L. ···Seto Marine Biological Laboratory, Sirahama.

LIST OF SPECIES

Stolonifera	
Clavularia inflata SCHENK	Ponape
Pachyclavularia violacea (QUOY et GAIMARD)	Bonins
Tubipora musica LINNAEUS	Palau
Telestacea	
Telesto trichostemma (DANA)	Palau
Alcyonacea	
Heteroxenia pinnata ROXAS	Palau
Microspicularia krempfi (HICKSON)	Palau
M. sphaerophora (EHRENBERG)	Bonins
Sinularia polydactyla (EHRENBERG)	Palau
S. flexibilis (QUOY et GAIMARD)	Palau
S. gardineri (PRATT)	Palau
Sarcophyton acutangulum (MARENZELLER)	Palau
S. digitatum MOSER	Palau
S. glaucum (QUOY et GAIMARD)	Palau
S. tenuispiculatum THOMSON et DEAN	Palau
S. trocheliophorum MARENZELLER	Palau
Lobophytum crebriplicatum MARENZELLER	Palau, Bonins
Capnella fungiformis KÜKENTHAL	Palau
Paralemnalia thyrsoides (EHRENBERG)	Palau
Nephthea chabrolii AUDOUIN	Palau
Dendronephthya köllikeri KÜKENTHAL	Palau
D. palaoensis UTINOMI	Palau
D. spinulosa (GRAY)	Palau
Coenothecalia	
Heliopora coerulea (PALLAS)	Palau
Gorgonacea	
Melithaea ochracea (LINNAEUS)	Palau
M. squamata (NUTTING)	Palau

Isis hippuris LINNAEUS — Palau
Plexaura flava NUTTING — Palau
Junceella squamata TOEPLITZ — Palau

Pennatulacea
Pennatula fimbriata HERKLOTS — Palau

STOLONIFERA

Family Clavulariidae HICKSON

Clavularia inflata SCHENK

Clavularia inflata UTINOMI, 1953, p. 150, text-figs. 1–2, pl. 8, figs. 1–2.

Material examined: Adult colonies attached to an ascidian *Polycarpa aurata* (QUOY et GAIMARD), Ponape Island, date and collector unknown (Z. I. T.).

Distribution: Philippines (Luzon), East Indies, Great Barrier Reef (Low Isles), Formosa, Southern Japan (Tokara Islands).

Pachyclavularia violacea (QUOY et GAIMARD)

Pachyclavularia violacea GOHAR, 1940, p. 20.
Clavularia violacea ROXAS, 1933a, p. 59.
Pachyclavularia erecta ROULE, 1908, p. 165, 3 figs.; MOLANDER, 1929, p. 24; THOMSON & DEAN, 1931, p. 19, pl. 2, figs. 4, 8 & 9; pl. 5, figs. 6, 7 & 9; pl. 16, figs. 1 & 2; MACFADYEN, 1936, p. 25.

Material examined: One colony growing on a stone, Titizima, Bonin Islands, April 1894, coll. S. HIROTA and R. SEKIGUCHI (Z. I. T.).

This extraordinary beautiful stoloniferan of bright reddish violet color, which was named by ROULE (1908) as *Pachyclavularia erecta* n. g. et sp., is so far little known, although it may not be less common on the coral reefs in the tropical West-Pacific region. Its peculiar structure was fully described by THOMSON and DEAN (1931) and the systematic position of the genus *Pachyclavularia* has already been discussed by MOLANDER (1929, p. 24), MACFADYEN (1936, p. 23) and GOHAR (1940, p. 17). The last-named author, who examined the type specimen of *Clavularia violacea* QUOY et GAIMARD preserved in the Muséum d'Histoire Naturelle, Paris, concludes that the two species, *violacea* and *erecta*, are synonymous. I am also of the same opinion on this point, but does not follow him in rejecting it from the Tubiporidae.

Distribution: Santa Cruz Islands (Vanikoro), East Indies, Philippines (Luzon), Great Barrier Reef (Wishart's Reef), Formosa (Garanbi).

Family Tubiporidae GRAY

Tubipora musica LINNAEUS

Material examined: dry specimens, Outer reef of Palau Islands, coll. H. UTINOMI (1934) and T. TOKIOKA (1940) (S. M. B. L.).

Distribution: Widespread in the tropical Indo-Westpacific.

TELESTACEA

Family Telestidae H. MILNE-EDWARDS

Telesto trichostemma (DANA)

(Fig. 1)

Telesto trichostemma LAACKMANN, 1908, p. 77; KÜKENTHAL, 1911, p. 326, text-figs. 42–44, pl. 21, fig. 14.

Material examined: 3 fragments, Ngarengelngael Passage (Geruherugairu Suidô) in Iwayama Bay, Koror Island, 1937, coll. T.YAMANOUCHI (S. M. B. L.).

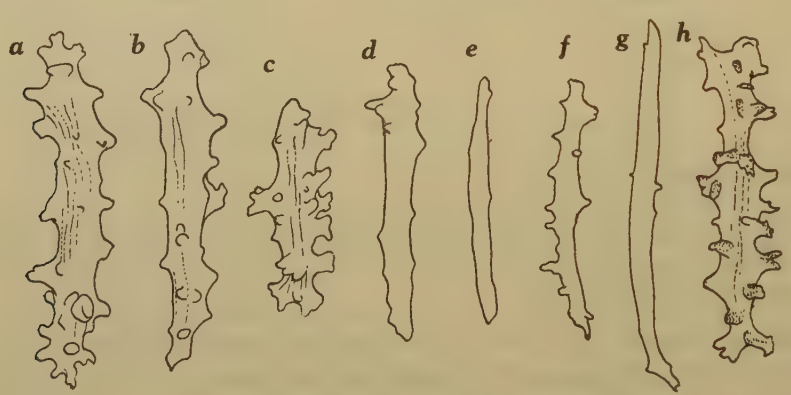


Fig. 1. *Telesto trichostema* (DANA).
Spicules of: *a–e*, polyps; *f–h*, stem (All ×150)

The specimens are fragmental, but all covered together by an encrusting siliceous sponge. The stem is slender, undivided, 23–33 mm in length and 0.8–1.2 mm in diameter; each may be branches issuing from a single colony. A few lateral polyps arise at an angle of about 40°. The height of polyps is up to 3 mm and the diameter about 1 mm. The coenenchyme is soft in texture and dirty white in color. Spicules are tuberculated rods, becoming more slender and smooth towards the tip of polyps, about 0.18×0.018 mm~0.3×0.07 mm. They are thickly disposed longitudinally on polyps and irregularly on stems. And they are interlocked with one another by virtue of their processes and occasionally fused together on stems.

Distribution: Fiji Islands, Torres Strait, Aru Islands, Maldive Islands.

HICKSON (1921, p. 369) recorded this species from Uraga Channel off Tokyo Bay, in 40–200 fathoms. From his brief note without figures, however, it is difficult to justify his identification on the Japanese specimen, since previous records are all from shallow sea of the tropical waters.

ALCYONACEA

Family Xeniidae VERRILL

Heteroxenia pinnata ROXAS

Heteroxenia elizabethae HIRO, 1937b, p. 237 (not KÖLLIKER's *elisabethae*).
H. pinnata ROXAS, 1933a, p. 102, pl. 4, fig. 9; UTINOMI, 1950, p. 86, fig. 2b.

Material examined: 8 specimens, reef flat of Ulebsehel (Oropusyakaru) Island, Palau Islands, 1934, coll. H. UTINOMI (S. M. B. L.). 3 specimens, the same place, 1934, coll. H. UTINOMI (Z. I. K.).

As I have already mentioned, this dimorphic xeniid is luxuriant on the reef flat only facing the outer lagoon around Ulebsehel Island, and the rhythmical movement of pulsating tentacles is easily observed in the field.

Distribution: Philippines (Mindoro Island), Palau Islands.

Family Alcyoniidae VERRILL

Microspicularia krempfi (HICKSON)

(Fig. 2, *a–k*)

Alcyonium Krempfi HICKSON, 1919, p. 411, figs. 1–2.
Lobularia Krempfi TIXIER-DURIVAULT, 1948, p. 96, figs. 88–93.

Material examined: 3 colonies, Koror Island, 1937, coll. T. YAMANOUCHI (S. M. B. L.).

The capitulum is cerebriform, round to oval in outline, measuring 4.5×3.2 cm, 5×3 cm and 7×4.5 cm in spread respectively and about 2 cm in height. Capitular lobes are rather large, round to polygonal 8 to 18 mm in longest diameter and 5 to 15 mm in height. Polyps are uniformly arranged on lobes, 0.7–0.9 mm in diameter and completely retractile. Tentacles, about 0.5 mm long, long-stalked, with usually 3-paired pinnules widened proximally, and bear on the back of median rachis tiny spicules, which are sometimes lacking. These spicules are finger-biscuit-like to elongate, smooth discs, from 0.025×0.01 mm to 0.037×0.011 mm, or feebly warted rods with a slight median constriction, from 0.052×0.023 mm to 0.06×0.034 mm. In cortex and coenenchyme of both the lobes and stalk are contained larger capstans with large rounded warts, which are wider than high, about 0.056×0.037 mm~0.1×0.075 mm.

Their shape is almost similar, but those in the basal coenenchyme are somewhat larger than in the lobular cortex.

Distribution: Nhatrang Bay (Vietnam), Seychelles, Madagascar.

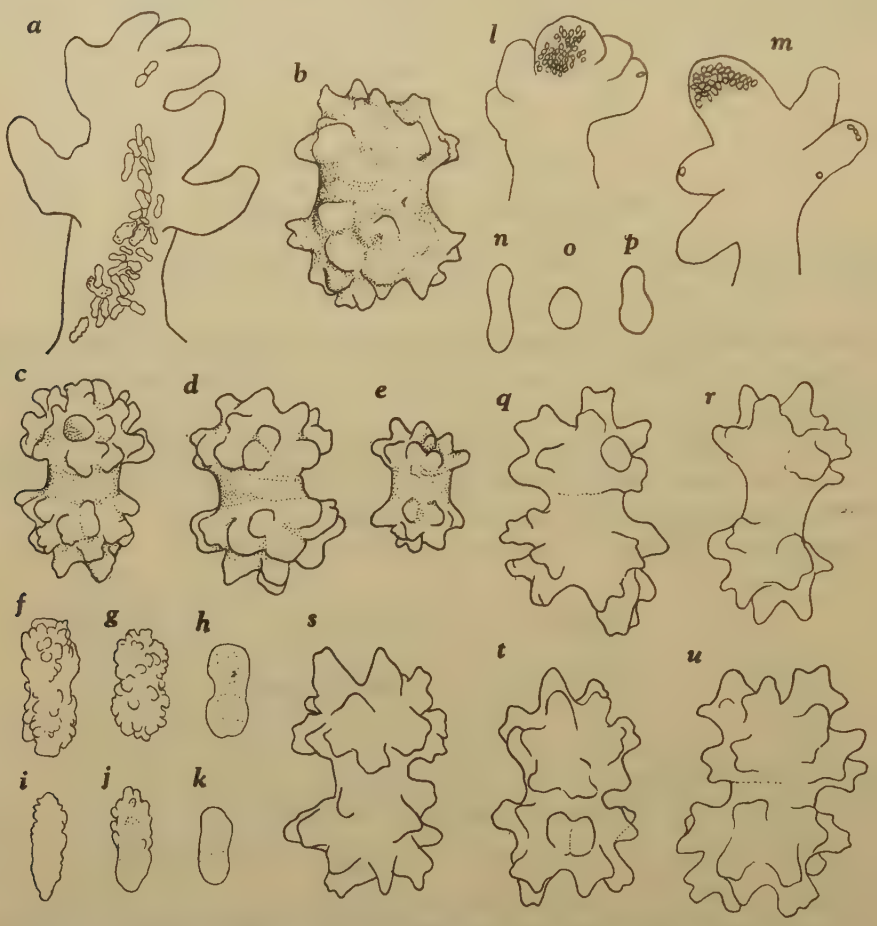


Fig. 2. *a–k, Microspicularia krempfi* (HICKSON): *a*, tentacle bearing spicules on axis alone; *b*, coenenchymal spicule of base; *c–e*, cortical spicules of lobes; *f–k*, spicules of tentacles. *l–u, Microspicularia sphaerophora* (EHRENBERG): *l–m*, tentacles bearing spicules at ends; *n–p*, spicules of tentacles; *q–r*, coenenchymal spicules of lobes; *s–t*, cortical spicules of lobes; *u*, cortical spicule of base.
(*a*, *l* and *m*, ×80; the rest, ×335)

Microspicularia sphaerophora (EHRENBERG)

(Fig. 2, *l–u*)

Alcyonium sphärophorum KLUNZINGER, 1877, p. 22, pl. 1, fig. 1.
Lobularia sphaerophora TIXIER-DURIVAULT, 1948, p. 29, figs. 15–19.

Material examined: 2 colonies, Anizima, Bonin (Ogasawara) Islands, April 1894, coll. S. HIROTA and R. SEKIGUCHI (Z. I. T.).

Both specimens are compressed, rounded oval in outline and cerebriform in upper surface. They measure respectively as follows:

47×39 mm in spread; 15 mm high.

50×35 mm in spread; 20 mm high.

Lobes rounded, 6×5 mm to 12×8 mm wide and 10 mm high. Zooids minute, 0.5–0.7 mm in diameter and count about 7 to a length of 5 mm. Cortical spicules are rather uniform: they are tuberculated capstans with a narrow median waist, about 0.065×0.035 mm~0.11×0.065 mm; the warts at both ends are broad and usually bifid at tip. In coenenchyme of lobes there are similarly shaped spicules, though with a narrower and longer median waist and roundly tipped warts. A cluster of finger-biscuit-shaped spicules, about 0.019–0.03 mm long, occur at the expanded axial end of tentacles and a few on two-paired pinnules.

Distribution: Red Sea, Madagascar, Zanzibar, Seychelles, Tahiti.

Sinularia polydactyla (EHRENBERG)

Material examined: 3 specimens, 5–11.5 cm in length, Palau Islands, March 1915, coll. S. TAKAHASHI (Z. I. K.).

This well-known sinulariid coral is very luxuriant around the reef edge of the Palau Islands, decreasing to the inner part of Iwayama Bay in abundance, and grows to a large size on the outer reef.

Distribution: Widespread in the Indo-Westpacific.

Sinularia flexibilis (QUOY et GAIMARD)

Material examined: A small specimen, 13 cm long, Palau Islands, March 1915, coll. S. TAKAHASHI (Z. I. K.).

The specimen shows a typical appearance of this remarkable species, bearing a number of long, flexible branches on the top of the stout cylindrical stalk with a height of 8 cm and a diameter of 2.8 cm. Terminal branches are finger-like up to 15 mm long, with a maximum diameter of about 3 mm and completely devoid of spicules. Cortical spicules of the stalk are irregular small clubs, 0.07 to 0.13 mm long, while in the interior occur heavy spindles with low rounded warts, though not thickly set, about 0.5×0.08 mm~1.5×0.18 mm. The stalk spindles are rather small compared with previous descriptions of this species as well as the other sinulariids.

Distribution: Vanikoro, Fiji, Samoa, Great Barrier Reef, East Indies, Vietnam, Philippines.

Sinularia gardineri (PRATT)

(Fig. 3, *a–m*)

Sinularia gardineri UTINOMI, 1954a, p. 50, fig. 6.

Material examined: 2 specimens, Ngarengelngael Passage in Iwayama Bay, Koror Islands, 1937, coll. T. YAMANOUCHI (S. M. B. L.).

Two flat colonies, both with a spread of 7×4 cm and a height of 2–3 cm, agree well with this species in the manner of growth and in the distinctive spiculation.

Fig. 3. *a–m*, *Sinularia gardineri* (PRATT): *a*, part of coenenchymal spindle; *b–g*, warty rods of stalk cortex; *h–l*, cortical clubs of stalk; *m*, warty rod of disc cortex. *n–x*, *Sarcophyton digitatum* MOSER: *n*, autozooid; *o*, cortical spicules of disc; *p–r*, coenenchymal spicules of disc; *s–u*, cortical spicules of stalk; *v–x*, coenenchymal spicules of stalk. (*n*, ×35; *l*, ×415; the rest, ×100)

The lobes scattered on the upper surface, about 5 mm apart from one another, are short, digitate in form, about 4–12 mm long and bluntly tipped, not subdivided. Cortical clubs about 0.08–0.11 mm long and 0.037 mm wide, with a knotty mass of warts, no central wart called as such being present at the tip of head. In addition, warty

rods up to 0.3 mm long occasionally occur. Coenenchymal spicules are large, heavily warted spindles up to 3 mm long.

Distribution: Red Sea, Ceylon, Maldives, East Indies, Great Barrier Reef, middle Japan (Kii coast).

Sarcophyton acutangulum (Marenzeller)

Material examined: A fragment 3.5 cm long, Koror Island, Palau Islands, 1937, coll. T. Yamanouchi (S. M. B. L.).

Distribution: Widespread in the Indo-Westpacific, as far north as Kii coast of middle Japan.

Sarcophyton digitatum Moser

(Fig. 3, *n–x*)

Sarcophyton digitatum Roxas, 1933b, p. 380, pl. 1, fig. 8; Macfadyen, 1936, p. 41.

Material examined: 2 colonies, 7–9 cm long, Palau Islands, March 1915, coll. S. Takahashi (Z. I. K.).

In both specimens, the stalk is long, cylindrical and the margin of the capitulum is regularly folded into 5 high folds, arising to a height of 4 cm, and projects far out of the stalk. Autozooids are very numerous, so thickly set on disc that only one siphonozooid between two autozooids. They are, when extended, 4 mm long and 0.6–0.8 mm in diameter. The spiculation of the disc and stalk is almost similar. Cortical spicules are warty rods or clubs, about 0.09×0.037 mm$\sim0.18\times0.056$ mm; the head of clubs is only irregularly knobby. Coenenchymal spicules are slender spindles feebly warted to wholly smooth, ranging from 0.18×0.015 mm to 0.28×0.028 mm in smooth form and from 0.45×0.035 mm to 0.7×0.04 mm in warted form. On aboral surface of the autozooids are seen smaller rod-like spicules.

Distribution: Philippines, Seychelles, Great Barrier Reef.

Sarcophyton glaucum (Quoy et Gaimard)

Material examined: A young, unfolded colony, 3 cm high and 2.4 cm wide, Palau Islands, March 1915, coll. S. Takahashi (Z. I. K.).

Distribution: Widespread in the Indo-Westpacific.

Sarcophyton tenuispiculatum Thomson et Dean

(Fig. 4)

Sarcophytum tenuispiculatum Thomson and Dean, 1931, p. 64, pl. 22, fig. 6.

Material examined: One specimen, Ngarengelngael Passage in Iwayama Bay, Koror Island, 1937, coll. T. Yamanouchi (S. M. B. L.).

A single specimen, dull brown in color, with the margin of disc convoluted into about 10 high and low folds, has a maximum disc diameter of 11 cm and a stalk 10 cm in height.

The margin of the disc is not thick, about 4–6 mm in thickness and projects only slightly over the slightly broadened apical portion of the stalk. Autozooids are 0.3 mm in diameter, about 1–1.5 mm apart, and there are about 9–11 autozooids to a centimeter at the margin. Siphonozooids are clear to the naked eye and only 2 between two autozooids at the margin, though 2–3 in the center of the disc.

The spiculation is very characteristic, differentiating into the following four regions.

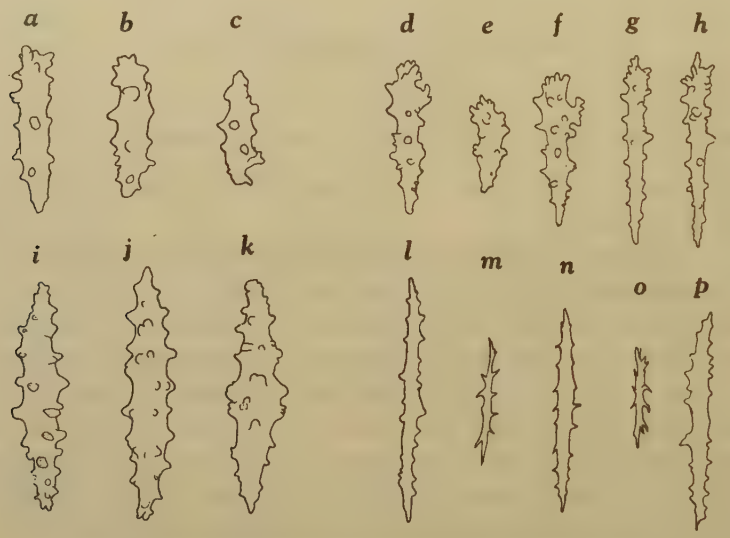


Fig. 4. *Sarcophyton tenuispiculatum* THOMSON et DEAN.
Spicules of: *a–c*, stalk cortex; *d–h*, disc cortex; *i–k*, stalk interior; *l–p*, disc interior. (All ×100)

(a) In the stalk cortex are mainly short warty rods which may be derived from the spindle type: 0.12×0.035 mm, 0.17×0.07 mm, 0.23×0.07 mm.

(b) In the stalk interior are all ordinary spindles with somewhat distant zoned warts: 0.25×0.05 mm, 0.3×0.07mm, 0.35×0.05 mm.

(c) In the disc cortex are deformed spindles or pseudoclubs: 0.12×0.05 mm, 0.16×0.05 mm, 0.26×0.04 mm.

(d) In the disc interior are delicate, slender spindles with relatively few, sharply pointed warts and pointed at both ends: 0.12×0.02 mm, 0.18×0.02 mm, 0.35×0.03 mm.

Remarks: Although the original description of *S. tenuispiculatum* (THOMSON and

DEAN, 1931), on which to base a judgment as to the identification, is far from satisfactory, the present specimen seems to me referable to it, especially in spiculation. The differences, if any, may be due to the size of the colony.

Distribution: Djampeah (Flores Sea, East Indies).

Sarcophyton trocheliophorum MARENZELLER

Material examined: One specimen, 7 cm high, Koror, Palau Islands, 1937, coll. T. YAMANOUCHI (S. M. B. L.).

Distribution: Widespread in the Indo-Westpacific, as far north as Tokara Islands, southern Japan.

Lobophytum crebriplicatum MARENZELLER

Material examined: One specimen, 7.5 cm high, koror, Palau Islands, March 1915, coll. S. TAKAHASHI (Z. I. K.)

One specimen, Turihama at Titizima, Bonin Islands, March 1894, coll. S. HIROTA and R. SEKIGUCHI (Z. I. T.).

Distribution: Tonga Islands, Low Isles, Madagascar, southern Japan (Tokara Islands).

Family Nephtheidae (VERRILL) emend. UTINOMI

Capnella fungiformis KÜKENTHAL

(Fig. 5)

Capnella fungiformis KÜKENTHAL, 1903, p. 133, pl. 7, fig. 5; pl. 9, figs. 30-32; THOMSON and MACKINNON, 1910, p. 179, pl. 5, fig. 11; THOMSON and DEAN, 1931, p. 71, pl. 10, figs. 2 and 5; MACFADYEN, 1936, p. 48.

Material examined: 3 specimens, 4–6 cm high, Palau Islands, March 1915, coll. S. TAKAHASHI (Z. I. K.).

Three brownish-gray colonies, the largest one of which has a height of 6 cm and a basal diameter of 4 cm, have a fungiform appearance characteristic to this species. Polyp-bearing lobes are 7–10 mm long and 5–6 mm in diameter, each covering densely incurved polyps about 1.8–2.2 mm long and 0.8–1.5 mm wide. The polyp armature consists of warty spindles (0.12×0.035 mm$\sim0.4\times0.15$ mm) which may be clavate owing to slight foliation at the thickened end. The sterile stalk shows heavily warted capstans, 0.05×0.017 mm$\sim0.2\times0.07$ mm and in the interior includes the typical jagged double-spheres (0.12×0.08 mm) or barrel-shaped spicules (0.2×0.15 mm), with sometimes no hint of median waist.

Distribution: Indian Ocean (Coetivy and Dar es Salaam), Great Barrier Reef (Low Isles), East Indies.

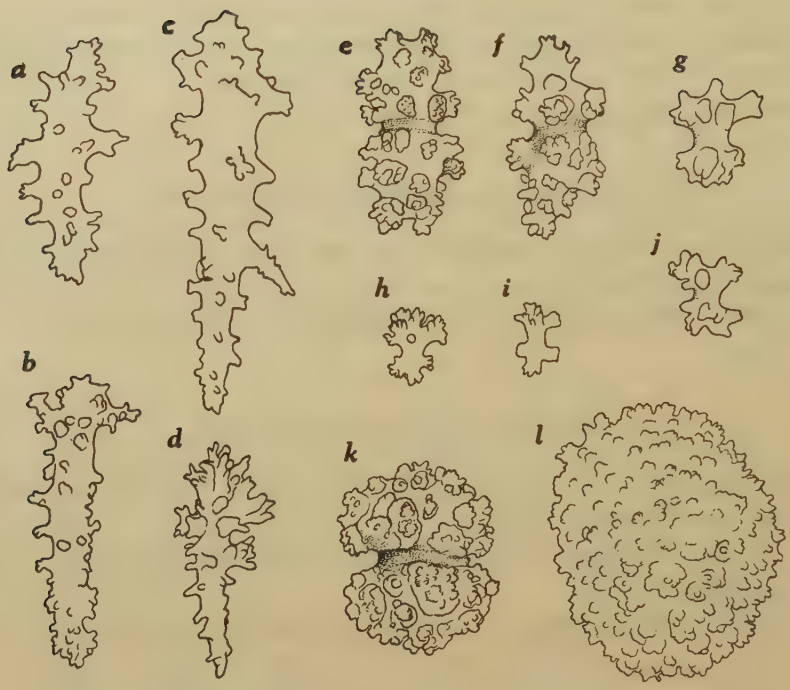


Fig. 5. *Capnella fungiformis* KÜKENTHAL.
Spicules: *a–d*, polyps; *e–j*, stalk cortex; *k–l*, stalk interior. (All ×150)

Paralemnalia thyrsoides (EHRENBERG)

(Fig. 6)

Ammothea thyrsoides KLUNZINGER, 1877, p. 31, pl. 2, fig. 3; MAY, 1900, p. 134, pl. 2, fig. 14 (var. *ramosa*).
Lithophytum thyrsoides THOMSON and HENDERSON, 1906, p. 427 (with var. *durum*).
Lemnalia thyrsoides THOMSON and DEAN, 1931, p. 76, pl. 9, figs. 2 & 6.
Paralemnalia thyrsoides KÜKENTHAL, 1913, p. 16; ROXAS, 1933b, p. 394, pl. 2, fig. 1; pl. 4, fig. 9; MACFADYEN, 1936, p. 55.

Material examined: One specimen. Ngarengelngael Passage in Iwayama Bay, Koror Island, 1934, coll. H. UTINOMI (S. M. B. L.).

The colony of this peculiar species, brownish in life, is very abundant on the sandy flat in the southern entrance of Iwayama Bay, Koror Island. The polyps are uniformly distributed all over the finger-like lobes, up to 7 cm long in the extended condition, arising from the membranous base. They are about 1 mm apart at the tip, more widely apart downwards and expand fully under the water. In the preserved material, the polyps are entirely retracted and the lobes are very brittle because of the spongy texture of the coenenchyme.

Distribution: Red Sea, Indian Ocean (Tumbatu, Zanzibar), East Indies, Great Barrier Reef (Yonge Reef), Philippines and southernmost cape of Formosa.

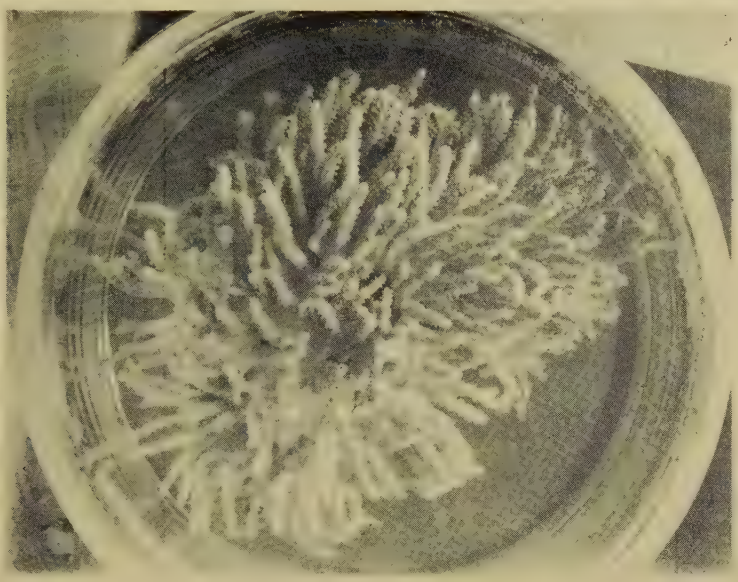


Fig. 6. *Paralemnalia thyrsoides* (EHRENBERG).
A living colony (photo by H. UTINOMI at Palau). (×¼)

Nephthea chabrolii AUDOUIN

Nephthea chabrolii UTINOMI, 1954b, p. 59, fig. 2 (with synonymy).

Material examined: One specimen, 6 cm long, Palau Islands, March 1915, coll. S. TAKAHASHI (Z. I. K.).

The general appearance and spiculation agree well with my former description of this species from Kii coast, middle Japan, excepting that the coenenchymal spicules of the stalk attain up to 3 mm long and 0.3 mm wide.

Distribution: Widespread in the Indo-Westpacific, as far north as middle Japan (Kii coast).

Dendronephthya köllikeri KÜKENTHAL

(Fig. 7)

Dendronephthya köllikeri KÜKENTHAL, 1905, p. 573, text-fig. J, pl. 27, fig. 15.

Material examined: One specimen, 11 cm long, Palau Islands, March 1915, coll. S. TAKAHASHI (Z. I. K.).

One specimen, 5 cm long, Palau Islands, collector and date unknown (Z. I. T.)

A large glomerate colony collected by S. TAKAHASHI consists of two main branches, about 7 cm long and a sterile stalk, about 4 cm long, which are generally flattened in one plane with a maximum width of 6.5 cm. Basal branches are numerous and foliaceous, encircling the top of the stalk.

Fig. 7. *Dendronephthya köllikeri* KÜKENTHAL.
a, polyp; *b–d*, spicules of stalk cortex; *e*, spicule of canal-walls.

Cortex of stalk and branches is thickly arranged transversely with remarkable white spicules up to 5 mm long. Downwards they become somewhat irregular in arrangement and contain triradiate or irregular-shaped smaller spicules, about 0.35 $\times$0.17 mm$\sim$2.5$\times$0.3 mm. Canal-walls are filled with 2 mm long and 0.3 mm wide plump spindles with flattened large warts scattered all over.

Polyps are compactly grouped and remarkable in very strongly projecting

supporting-bundle spicules of which the longest one is up to 5 mm long. Point spicules are distantly arranged in eight rows, each in 2 or 3 pairs; uppermost one is hockey-club-shaped, up to 1 mm long and highly projects for about 0.3 mm long beyond polyp-head. Dorsal and ventral rows are occasionally unpaired. Thus the formula of anthocodial armature follows:

$$IV=1P+(1-2)\,p+0\,Cr+\text{very strong S. B.}+0\,M$$

These anthocodial spicules are brownish or orangish yellow, while the other spicules colorless.

Distribution: This species, originally recorded from the Palaus, is so far unknown elsewhere.

Dendronephthya palaoensis UTINOMI

Dendronephthya palaoensis UTINOMI, 1952, p. 140, text-fig. 11, pl. 10, fig. 11.

Material examined: One specimen, Koror Island, Palau Islands, 1937, coll. T. YAMANOUCHI (S. M. B. L.).

This species belonging to the divaricate group has been fully described in my former paper given above.

Dendronephthya spinulosa (GRAY)

Dendronephthya spinulosa UTINOMI, 1952, p. 191, text-fig. 18, pl. 10, fig. 14.

Material examined: One specimen, Palau Islands, March 1915, coll. S. TAKAHASHI (Z. I. K.).

The specimen here examined from Palau is gigantic, probably of the greatest size in this group, next to *D. maxima* KÜKENTHAL (78 cm long) from Sagami Bay. Namely it is about 60 cm in total length of which 42 cm belongs to the sterile stalk. The stalk is gradually tapering upwards, the diameter being about 11 cm at the base and only 2 cm at the top. The polyparium is formed of three main branches, measuring respectively 9 cm, 12 cm and 18 cm in length. In addition, there are two foliaceous branchlets at the base of polyparium.

The spiculation exactly agrees with that of the Japanese specimen, though the anthocodial armature is not so brittle as previously noted.

All polyp spicules are orangish, the upper branches white, while the stalk brownish red.

Distribution: Indian Ocean, China Sea, middle Japan (Tanabe Bay).

COENOTHECALIA

Family Helioporidae MOSELEY

Heliopora coerulea (PALLAS)

Heliopora coerulea EGUCHI, 1938, p. 387; EGUCHI, 1948, p. 362, pl. 60, figs. 3, 4 & 6; UTINOMI, 1953, p. 159.

Material examined: Several dry specimens, outer reef of Palau Islands, 1934, coll. H. UTINOMI (S. M. B. L.).

As was noted in my paper on the cirripeds of the Palau Islands, the blue coral occurring commonly in the Palau Barrier Reef is sometimes infested with a peculiar barnacle, *Tetraclita* (*Tesseropora*) *wiréni* NILSSON-CANTELL (HIRO, 1937a, p. 68, pl. 3, fig. 4). Its occurrence in the coral is only detectable by a circular pore on the surface of the coral. According to EGUCHI (1948), frequently this is also perforated by commensal or parasitic worms (probably a kind of polychaetes).

Distribution: Widespread in the Indo-Westpacific, as far north as Ryûkyû Islands.

GORGONACEA

Family Melithaeidae (GRAY) emend. RIDLEY

(=Melitodidae WRIGHT et STUDER)

*Melithaea** *ochracea* (LINNAEUS)

(Fig. 8, *a–k*)

Melitodes ochracea KÜKENTHAL, 1911, p. 334, text-figs. 54–60, pl. 23, fig. 20; NUTTING, 1911, p. 38; HICKSON, 1932, p. 469; HICKSON, 1937, p. 97, figs. 5–7; STIASNY, 1940, p. 218, text-fig. E, pl. 9, figs. 12–13; pl. 14, figs. 34–35.

Material examined: 2 dry specimens, Palau Islands, 1937, coll. T. YAMANOUCHI (S. M. B. L.).

Two colonies of this well-known species, 28 cm and 22 cm long respectively, are both irregularly fan-shaped in growth and scarcely reticulate around the main stems. The main stems are somewhat flattened measuring as 10×13 mm to 11×14 mm in

* Since the emendation by VERRILL (1864), the name *Melitodes* has long been used for the genus as a substitute name for *Melitea* or *Melitaea*. However, the other older name *Melithaea*, which has been used by H. MILNE-EDWARDS (1857), KÖLLIKER (1865) and GRAY (1870), but not by later workers, is not to be treated as a homonym of such names according to the latest Copenhagen Decision on Nomenclature (1953). There is no decisive evidence to prove whether it is a substitute name for *Melitaea* or the result of only an inadvertent error in spelling, but the new genus name *Melitodes* was not accepted by GRAY (1870), merely quoting a suggestion of VERRILL without comment. For the above reasons it seems better to retain the name *Melithaea* for the genus instead of *Melitodes*.

diameter and the branches run almost parallel to the main stems. The nodes are distinctly hollowed on outer surface and separated on an average by a length of 15 mm (13–20 mm). The polyps are usually distributed on one side of the flabellum and they are mostly small, about 0.45 mm in diameter.

The anthocodial armature, as illustrated by HICKSON and STIASNY, consists of eight chevroned rows of curved spindles, about 4 pairs in each point, arranged above

Fig. 8. *a k, Melithaea ochracea* (LINNAEUS): *a*, polyp; *b–h*, coenenchymal spicules; *i*, spicule of node; *j–k*, point spicules. *l–z, Melithaea squamata* (NUTTING): *l*, polyp; *m–t*, coenenchymal spicules; *u*, spicule of node; *v–w*, point spicules; *x–z*, tentacle spicules. (*a* and *l*, ×80; the rest, ×335)

a collaret ring composed of two straight spindles transversely placed; they measure 0.088×0.017 mm～0.16×0.07 mm. The coenenchyme is filled with spindles, clubs and their deformed oval forms with large blunt tubercles, 0.035×0.03 mm～0.1×0.05 mm. The node includes smooth rodlets, about 0.08–0.1 mm long.

The color of the entire colony is red, but the spicules are orange or colorless in the coenenchyme and yellow in the anthocodiae.

Distribution: Indian Ocean, East Indies, Great Barrier Reef.

Melithaea squamata (NUTTING)

(Fig. 8, *l–z*)

Melitodes squamata NUTTING, 1911, p. 41, pl. 7, fig. 1; pl. 12, fig. 1; HICKSON, 1937, p. 120.
M. squamosa KÜKENTHAL, 1919, p. 150; KÜKENTHAL, 1924, p. 62 (erroneous spelling of *squamata*).

Material examined: One colony broken into fragments, Palau Islands, March 1915, coll. S. TAKAHASHI (Z. I. K.).

The specimen, though incomplete, is undoubtedly flabellate and not reticulate in growth, as in the original description of this species. The main stem is round in cross section, about 12 mm in diameter, but the branchlets are somewhat compressed. All the branches are borne on the horny nodes where are much swollen. Polyps are distributed on three sides, leaving the back of the flabellum bare, but as a rule they are arranged in two lateral rows on branches, with a few scattered between them on a median upper surface of the stem. The verrucae are remarkably small for the size of the colony, the usual diameter being only 0.5 mm. They are crimson red in conflict with the yellow color of the coenenchyme of the colony. The nodes and internodes of the axis have the same color as the verrucae, though the tentacles are pale yellow to colorless.

The spicules are almost alike those of the preceding species, although the anthocodial spicules of the points (0.12–0.25 mm long) are fewer in number. The coenenchyme is filled with very small, yellow spicules, mostly tuberculated spheres (usually 0.05×0.04 mm). In the verrucae, the tuberculated spicules are more or less larger, including ovals or club-like forms (0.035×0.017 mm～0.09×0.035 mm). The nodes are thickly filled with smooth rodlets of orangish color, about 0.035–0.085 mm long.

Distribution: East Indies (off Timor), 34 m (type locality).

Family Isididae STUDER

Isis hippuris LINNAEUS

Isis hippuris SIMPSON, 1906, p. 421, pl. 43; KÜKENTHAL, 1924, p. 443; HICKSON, 1932, p. 470; HICKSON, 1938, p. 596.

Material examined: 3 bleached fragments, 13 cm, 16 cm and 18 cm in length, Helen Reef, southernmost of Palau Islands, 1937, coll. T. YAMANOUCHI (S. M. B. L.).

This well-known species is represented in the collection by three imperfect specimens, lacking all the coenenchyme and attachment bases. It is easily identified, however, by the white calcareous internodes furrowed longitudinally and the brown horny nodes markedly constricted, alternating one another. The maximum diameter of the axis is about 5 mm where about 20 low ridges encircle.

Distribution: Indo-Westpacific in shallow seas.

Family Plexauridae GRAY

Plexaura flava NUTTING

(Fig. 9, *a–i*)

Plexaura flava NUTTING, 1910, p. 8, pl. 2, fig. 1; pl. 4, fig. 6; STIASNY, 1935, p. 55, text-fig. P, pl. 4, fig. 21; STIASNY, 1940, p. 239.
Euplexaura flava KÜKENTHAL, 1924, p. 100.

Material examined: A single specimen, 22 cm long, Palau Islands, March 1915, coll. S. TAKAHASHI (Z. I. K.).

The specimen agrees well with NUTTING's description and figures of this species. The colony in alcohol is light Naples yellow in color, with the brown axis. The branchlets are given off in a pinnate arrangement from the main stem and primary branches, at intervals of 3–7 mm and at an angle of about 60°–70° to the axis. The calyces, about 0.4 mm in diameter, are very low and evenly distributed on all sides of the branches. Spicules of the coenenchyme are coarsely warted spindles, sometimes pointed at one end, about 0.1×0.035 mm$\sim 0.32 \times 0.05$ mm. Anthocodial spicules are only smooth rodlets, 0.09×0.0012 mm.

Distribution: East Indies, Sulu Archipelago.

Family Gorgonellidae STUDER

Junceella squamata TOEPLITZ

(Fig. 9, *j–q*)

Junceella squamata TOEPLITZ, 1929, p. 257, text-fig. 1, pl. 6, fig. 1; STIASNY, 1940, p. 246.

Material examined: 5 dry specimens, 49–64 cm long, Lebugol Channel, Koror Island, Palau Islands, 1937, coll. T. YAMANOUCHI (S. M. B. L.).

The colonies are unbranched, whip-like and dirty white in the dried condition, though two of them are fused together at base. The diameter of the stem does not differ much throughout; in one specimen, for example, it is 7 mm at base while 4.5 mm at the terminal end. The proximal part, about 2–4 cm in length, is usually sterile,

but with a slight median longitudinal furrow, suggesting a biradial arrangement of polyps. The coenenchyme is comparatively thick and filled with asymmetrical double-clubs whose heads have smooth warts, about 0.075×0.047 mm~0.083×0.047 mm. The verrucal spicules are narrower and more asymmetrical in form than those of the coenenchyme, about 0.07×0.018 mm~0.084×0.028 mm.

Distribution: Philippines, Formosa, East Indies.

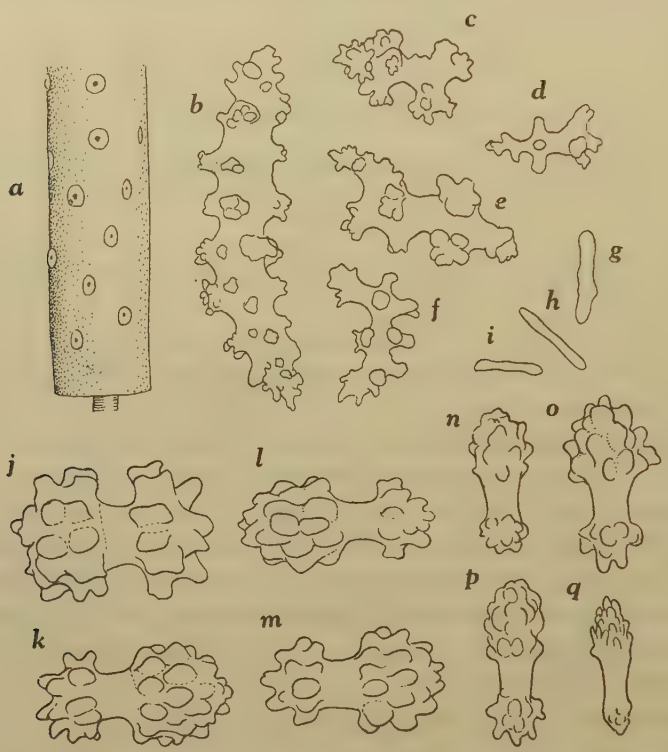


Fig. 9. *a–i*, *Plexaura flava* NUTTING: *a*, part of branchlet; *b–f*, coenenchymal spicules of main stem; *g–i*, polyp spicules. *j–q*, *Junceella squamata* TOEPLITZ: *j–m*, stem spicules; *n–q*, verrucal spicules. (*a*, ×5; *b–i*, ×150; *j–q*, ×335)

PENNATULACEA

Family Pennatulidae KÖLLIKER

Pennatula fimbriata HERKLOTS

Material examined: 2 specimens, both 23 cm long, Ngarengelngael Passage, Koror Island, 1937, coll. T. YAMANOUCHI (S. M. B. L.).

Distribution: Japanese and Malayan Seas.

LITERATURE

EGUCHI, M. 1938. A systematic study of the reef-building corals of the Palao Islands. Palao Trop. Biol. Sta. Studies, 1 (3): 325–390.

———— 1948. Fossil Helioporidae from Japan and the South Sea Islands. Journ. Paleont., 22 (3): 362–364, pl. 60.

GOHAR, H. A. F. 1940. A revision of some genera of the Stolonifera. Publ. Mar. Biol. Sta. Ghardaqa (Red Sea), 3: 1–23, 1 pl.

GRAY, J. E. 1870. Catalogue of Lithophytes or stony corals in the collection of the British Museum. 51 pp. London.

GRESSITT, J. L. 1954. Insects of Micronesia. Introduction. Insects of Micronesia, 1: ix+257 pp.

HICKSON, S. J. 1919. Sur quelques specimens d'un *Alcyonium* d'Annam *Alcyonium krempfi* n. sp. Bull. Soc. Zool. France, 44: 411–424.

———— 1921. On some Alcyonaria in the Cambridge Museum. Proc. Cambridge Phil. Soc., 20 (3): 366–373.

———— 1932. Gorgonacea. Great Barr. Reef Exped., Sci. Rep., 4 (13): 459–512.

———— 1937. The family Melitodidae. Trans. Zool. Soc. London, 23 (3): 73–209, pl. 14.

———— 1938. The Gorgonacea from Torres Straits collected by Prof. A. C. Haddon, F.R.S., 1888-1889, with notes on the genera *Hicksonella* and *Pseudothesea*. Proc. Zool. Soc. London, 108 (3): 585–610.

HIRO, F. 1937a. Cirripeds of the Palao Islands. Palao Trop. Biol. Sta. Studies, 1 (1): 37–72, pl. 3.

———— 1937b. Observations on the alcyonarian *Heteroxenia elizabethae* Kölliker. Annot. Zool. Japon., 16 (3): 237–244.

KLUNZINGER, C. B. 1877. Korallthiere des Rothen Meeres. Erster Theil: Die Alcyonarien und Malacodermen. vii+94 pp., 7 pls. Berlin.

KÜKENTHAL, W. 1903. Versuch einer Revision der Alcyonarien. II. Die Familie der Nephthyiden. 1 Theil. Zoöl. Jahrb. Abt. Syst., 19 (1): 99–172, pls. 7–9.

—— ———— 1905. Versuch einer Revision der Alcyonarien. II. Die Familie der Nephthyiden. 2 Teil. Die Gattungen *Dendronephthya* n. g. und *Stereonephthya* n. g. Ibid., 21 (5/6): 503–726, pls. 26–32.

———— 1911. Alcyonarien von den Aru- und Kei-Inseln nach den Sammlungen von Dr. H. Merton. Abh. Senckenb. naturf. Ges. Frankfurt, 33 (4): 305–346, pls. 19–23.

———— 1919. Gorgonaria. Wiss. Ergeb. der Deut. Tiefsee-Exped., 13 (2): 1–948, pls. 30–89.

———— 1924. Gorgonaria. Das Tierreich, 47 Lieferung, xxviii+478 pp. Berlin u. Leipzig.

LAACKMANN, H. 1909. Zur Kenntnis der Alcyonarien-Gattung *Telesto* Lmx. Zool. Jahrb. Suppl. 11 (1): 41–104, pls. 2–8.

MACFADYEN, L. M. I. 1936. Alcyonaria (Stolonifera, Alcyonacea, Telestacea and Gorgonacea). Great Barr. Reef Exped., Sci. Rep., 5 (2): 19–71, pls. 1–3.

MAY, W. 1900. Beiträge zur Systematik und Chorologie der Alcyonaceen. Jena. Z. Naturw., 33: 1–180, pls. 1–5.

MOLANDER, A. R. 1929. Die Octactiniarien. Further Zool. Res. Swedish Antarctic Exped., 2 (2): 1–86, pls. 1–4.

NUTTING, C. C. 1910. The Gorgonacea of the Siboga Expedition, IV. The Plexauridae. Siboga-Exped., Monog. 13b[1], Livr. 48. 20 pp., 4 pls. Leiden.

———— —— 1911. The Gorgonacea of the Siboga Expedition, VIII. The Scleraxonia. Ibid., Monog. 13b[5], Livr. 57. 62 pp., 12 pls. Leiden.

ROULE, L. 1908. Alcyonaires d'Amboine. Rev. Suisse Zool., 16 (2): 161–194, pls. 6–8.

ROXAS, H. A. 1933a. Philippine Alcyonaria. The families Cornulariidae and Xeniidae. Philip. Journ. Sci., 50 (1): 49–110, pls. 1–4.

ROXAS, H. A. 1933b. Philippine Alcyonaria, II. The families Alcyoniidae and Nephthyidae. Ibid., 50 (4) : 345 470, pls. 1–5.

SIMPSON, J. J. 1906. The structure of *Isis hippuris*, Linnaeus. Journ Linn. Soc. London, Zool., 37 : 421 433, pl. 43.

STIASNY, G. 1935. The Gorgonacea der Siboga-Expedition. Supplement I. Revision der Plexauridae. Siboga-Exped., Monog. 13b^{7}, Livr. 124, vi+106 pp., 7 pls. Leiden.

———— 1940. Biological results of Snellius Expedition, VII. Die Gorgonarien-Sammlung der Snellius-Expedition. Temminckia, 5 : 191–256, pls. 6–14.

THOMSON, J. A. and DEAN, L. M. I. 1931. The Alcyonacea of the Siboga Expedition, with an appendam to the Gorgonacea. Siboga-Exped., Monog. 13d, Livr. 115. 227 pp., 28 pls. Leiden.

———— and HENDERSON, W. D. 1906. The marine fauna of Zanzibar and British East Africa from collections made by Cyvil Crossland in the years 1901–1902.—Alcyonaria. Proc. Zool. Soc. London, 1906 (1) : 393 443, pls. 26–31.

———— and MACKINNON, D. L. 1910. Alcyonarians collected on the Percy Sladen Trust Expedition by Mr. J. Stanley Gardiner, M.A., F.R.S. Part 2. The Stolonifera, Alcyonacea, Pseudoxonia and Stelechotokea. Trans. Linn. Soc. London, Ser. 2, 13 (Zool.) : 165–211, pls. 6–14.

TIXIER-DURIVAULT, A. 1948. Révision de la famille des Alcyoniidae. Genre *Lobularia*. Mém. Mus. Nation. d'Hist. Nat., N. S., 23 (1) : 1 256.

TOEPLITZ, Ch. M. 1929. Die Gorgonarien Westindiens. Kap. 7, Die Familie Gorgonellidae, zugleich eine Revision. Zool. Jahrb., Suppl., 16 (2) : 235–376, pls. 6–7.

UTINOMI, H. 1950. Some xeniid Alcyonarians from Japan and adjacent localities. Publ. Seto Mar. Biol. Lab., 1 (3) : 81–91.

———— 1952. *Dendronephthya* of Japan, I. *Dendronephthya* collected chiefly along the coast of Kii Peninsula. Ibid., 2 (2) : 161–212, pls. 9–11.

———— 1953. Invertebrate fauna of the intertidal zone of the Tokara Islands. VI. Alcyonaria. Ibid., 3 (2) : 149 160, pl. 8.

———— 1954a. Some Alcyoniid octocorals from Kii coast, middle Japan. Ibid., 4 (1) : 43–55, pl. 1.

———— 1954b. Some Nephtheid octocorals from Kii coast, middle Japan. Ibid., 4 (1) : 57–66, pl. 2.

VERRILL, A. E. 1864. List of the polyps and corals sent by the Museum of Comparative Zoölogy to other institutions in exchange, with annotations. Bull. Mus. Comp. Zoöl. Harvard Coll., 1 : 29–60.

WRIGHT, E. P. and STUDER, Th. 1889. Report on the Alcyonaria collected by H.M.S. Challenger during the years 1873–76. Challenger Report, Zoology, 31 (64) : lxxii+314 pp., 43 pls. London.

ON THE SO-CALLED "UMI-UTIWA," A PECULIAR FLABELLATE GORGONACEAN, WITH NOTES ON A SYLLIDEAN POLYCHAETE COMMENSAL[1]

Huzio UTINOMI
Seto Marine Biological Laboratory, Sirahama

With Plate XXVII and 2 Text-figures

Along the Pacific coast of southern Japan, a large gorgonacean colony of flabellate branching, which is usually known as "Umi-utiwa",[2] is occasionally found, as stranded on the beach or caught by fishermen's nets. The stranded colony is usually almost denuded without bark while being cleaned ashore, so that anyone who happened to see it cannot decide to which kind of the Gorgonacea it should be referred.

The axis of the colony is very firm in texture, dark brown to black in color and flabellate with dense anastomoses in outline. A similar, possibly the same, gorgonacean coral is listed or figured under the name "*Rhipidogorgia*" in many representative textbooks of zoology published in Japan.[3] This is evidently an erroneous identification due to the superficial resemblance in the flabellate growth form, since the gorgonacean named as such (exactly *Gorgonia flabellum* Linnaeus, syn. *Rhipidogorgia flabellum*) is a separate species living only on the Atlantic coast of North America and in the West Indies (Bayer, 1951).

While examining the gorgonacean materials, a number of living and dead colonies referable to this so-called "Umi-utiwa" from various localities came to my hand. On examination on the spiculation and other structures, I came to a conclusion that they should be referred to a Muriceid holaxonian, *Anthogorgia bocki* Aurivillius (1931), originally recorded from the Bonin Islands.

Moreover, I found that the living colonies of this species are frequently infested with a polychaete commensal belonging to the syllid genus *Haplosyllis*.

---

1) Contributions from the Seto Marine Biological Laboratory, No. 280.

2) "Umi-utiwa" or "Umi-uchiwa" means a sea-fan in Japanese. A similar name is given also for a marine brown alga, *Padina arborescens* Holmes.

3) For example, see I. Ijima's "A manual of zoology (Dôbutugaku Teiyô)" (1918), p. 333, fig. 386; N. Yatsu's "Classification table of animals (Dôbutu Bunruihyô)" (1920, 1923), p. 41; Iwanami's "Zoological dictionary (Dôbutugaku Ziten)" (1935), p. 908.

Descriptions of *Anthogorgia bocki* AURIVILLIUS

(Text-fig. 1 and Pl. XXVII)

1. Specimens from Seto and Kii-ôsima, Wakayama Pref., Honsyû.

In the Museum of our Laboratory, there are at present four large and small colonies. Among them an incomplete colony from Kii-ôsima (Pl. XXVII, Fig. 3), about 24 cm long, obtained in 1940, and a complete colony from Seto, about 35 cm long and 23 cm wide, obtained in January 1955, are wholly covered with a thin bark. Of the remaining two from Seto, which are entirely naked and dry, the largest one obtained on September 6, 1944 (Pl. XXVII, Fig. 2) is about 60 cm in height and 40 cm in width. Its basal attachment is now lacking, but the main stem at the base measures 11×8 mm in diameter.

Entire colony flabellate, branched in one plane, with profuse anastomoses of both large and small branches. Branching sinuous and irregular. Larger branches flattened at right angles to the plane of branching, whereas small twigs are round in cross section, less than 1 mm in diameter, arising perpendicularly from the flattened lateral sides of main stem and larger branches. Axis purely horny, stout, dark brown to black, and marked by longitudinal grooves; but at end-twigs it is sometimes naked, leaving only its central chord which is about 0.35–0.45 mm in diameter, soft, flexible, chambered internally and colored olive or light brown (Fig. 1 *g*).

Polyps occur on all sides of the colony, relatively sparsely on larger branches, becoming more densely and more numerous toward smaller branches. Polyps short tubular, roundly tipped, with 8-rayed orifice at its center; they are usually about 1 mm in diameter and 1–1.8 mm in height in retracted condition. Verrucal walls densely covered with fusiform, strongly warted, about 0.3–0.4 mm long spicules arranged transversely; at their tip similar spindles formed of eight points of 3 to 5 pairs, each clustered in a triangle, which close over the tentacles in retraction, forming together an operculum. Tentacles, folding within the orifice, bear about 0.18–0.28 mm long warty spicules longitudinally placed and about 0.05–0.1 mm long rodlike pinnular spicules laterally.

Bark moderately thin, easily rubbed off, covered with layer of large, bluntly-ended warty spindles as long as 1.3 mm; deeper layer of generally smaller spindles or rods with bifurcate ends between them. Color of bark and all sclerites orangish in life, though faded in spirit.

Spicule measurements—

Opercular (point) spindles: 0.3×0.09 mm, 0.35×0.09 mm, 0.4×0.1 mm.
Outer stem spindles: 0.35×0.09 mm, 0.45×0.12 mm, 0.5×0.14 mm, 0.6×0.16 mm, 0.8 ×0.18 mm, 0.9 ×0.29 mm, 1.1×0.23 mm, 1.3×0.35 mm.
Smaller stem rods: 0.07×0.035 mm, 0.09×0.07 mm, 0.12×0.04 mm, 0.18×0.05 mm.

2. Specimen from Tomioka, Kumamoto Pref., Kyûsyû.

In the Amakusa Marine Biological Station of Kyusyu University at Tomioka, a

magnificent large colony (Pl. XXVII, Fig. 1) is preserved. Its total height is about 60 cm and maximum width is about 67 cm, though lacking the base of attachment. It is wholly dry, but the branches are densely reticulate and the bark with polyps remained here and there, especially near the center of the somewhat hollowed upper surface of

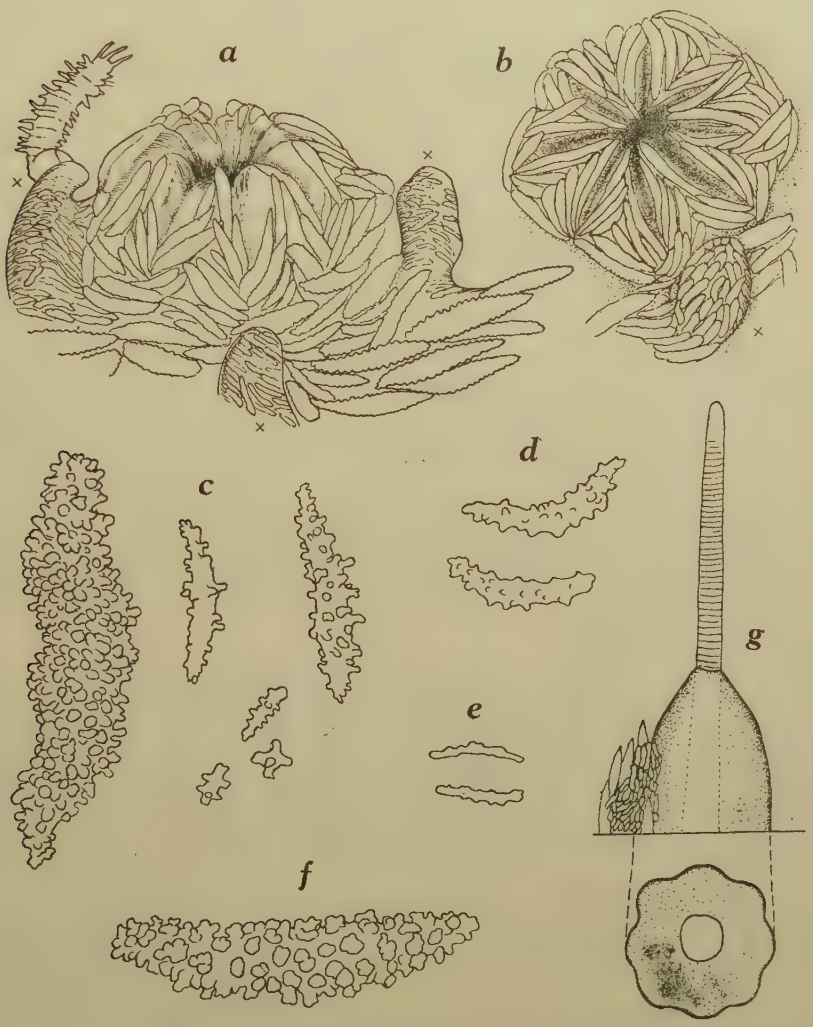


Fig. 1. *Anthogorgia bocki* AURIVILLIUS from Seto.

a, A retracted polyp, with three dwellings of commensal syllid around it (indicated by a cross mark (×), viewed from side, ×35; *b*, upper view of retracted polyp, with a dwelling of commensal syllid (×) at base, ×35; *c*, stem spicules, of which the largest one from outer layer of bark and the remainder from the inner layer, ×150; *d*, tentacle spicules, ×510; *e*, pinnular spicules, ×510; *f*, point spicule, ×510; *g*, denuded end of twigs, showing a central chord terminally and layered spicular coverings on axis (above) and a cross-section of axis (below), somewhat diagrammatic.

the flabellum, the outer edges being slightly bent upward. Small twigs ending freely occur densely on the upper surface and are all bent upward. Denuded axis is brownish black, smaller twigs dark brown, while the remained bark brownish white or colorless.

3. Specimen from Inan coast, Ehime Pref., Sikoku.

In the Biological Institute of Ehime University at Matuyama, there is also a large incomplete colony, probably referable to this species. The specimen is dry and entirely devoid of bark.

Remarks. Inasmuch as I have consulted, nine species have been described as belonging to the genus *Anthogorgia*: *A. divaricata* VERRILL (1866), *A. japonica* STUDER (1889), *A. verrilli* THOMSON & HENDERSON (1906), *A. racemosa* THOMSON & SIMPSON (1909), *A. glomerata* THOMSON & SIMPSON (1909), *A. aurea* NUTTING (1910), *A. grandiflora* KÜKENTHAL (1924) (=*A. verrilli* NUTTING, 1910), *A. annectens* THOMSON & DEAN (1931) and *A. bocki* AURIVILLIUS (1931). Most of these species have cylindrical polyps rising to a height of 3–4 mm and flabellate branches with or without anastomosis. The last-named *bocki*, to which I have referred the specimens here described, has not yet been recorded since the original report. But as inferred from this finding from various localities, this species may be common in the southern Japan.

The type specimen of *A. bocki* from Bonin Islands is, according to AURIVILLIUS, 19 cm long and 26 cm wide, with the basal portion of stem only 5 mm in diameter, and the anastomoses are occasional, but not dense. It is thus smaller and younger than those I have examined.

As regards the systematic position of the genus *Anthogorgia* VERRILL (1868, 1869), most of the former authors are right in placing it in the family Muriceidae GRAY. Only exceptionally, GORDON (1926, p. 510, foot-note) and AURIVILLIUS (1931) are of opinion that *Anthogorgia* (according to GORDON, together with *Boarella* GRAY and *Versluysia* NUTTING, and according to AURIVILLIUS, together with *Eumuricea* VERRILL) should be included in the family Acanthogorgiidae KÜKENTHAL rather than in the Muriceidae.

STIASNY (1940) recorded *A. japonica* and *A. grandiflora* from Red Sea, both placing in the Muriceidae, but later (1943, p. 130; 1947, p. 84) proposed to transfer *A. bocki* alone amongst the species of *Anthogorgia* to the genus *Acalycigorgia* in the Acanthogorgiidae, basing solely on the description of AURIVILLIUS and partly accepting his first intention to refer to the same genus. Both authors' view cannot be supported for the specimens of *Anthogorgia* and *Acalycigorgia* at hand.

Although the separation of the family Acanthogorgiidae from the family Muriceidae is not entirely satisfactory, as criticized by HICKSON (1930), the majority of the acanthogorgiids have very prominent, long, 'non-retractile' calyx whose spicules form generally 8 ridges in the longitudinal direction of the polyp, and do not form any collaret ring. The so-called 'operculum' which is usual in the muriceid corals is absent

or indistinct. In the present *A. bocki*, however, as in other muriceids, the anthocodial part of polyps, where uppermost spicules of eight points form together the operculum, is more or less retractile into tubular verrucae, though the points of the operculum are not entirely withdrawn into it. Although there is no spiculeless neck zone below the operculum, the retractibility of the anthocodia is aided by the transverse arrangement of verrucal spicules in the lower part of polyps. In these respects, *Anthogorgia* is most closely related to the genus *Calicogorgia* (e.g. *C. granulosa* KÜKENTHAL & GORZAWSKY) amongst the Muriceidae. In the latter genus, however, the point spicules are not so regularly arranged *en chevron* and the verrucal spicules are more irregularly distributed.

Descriptions of a polychaete commensal *Haplosyllis anthogorgicola* sp. nov.

(Text-fig. 2)

As already mentioned in the original description of *Anthogorgia bocki* (AURIVILLIUS, 1931), numerous abnormal outgrowths of the bark between the polyps are usually met with in all specimens of this gorgonacean clothed with bark. The tip of these outgrowths projects in a tubular form over the general surface of the bark, not exceeding the height of polypal verrucae and is usually bent slightly. They are all covered irregularly with fusiform spicules, smaller than those on the normal bark, and open at the end. These tube-like swellings or flaps are inhabited each by a small commensal polychaete referable to the genus *Haplosyllis* (sometimes treated as a subgenus of *Syllis*).

Syntypes: Many males and females from Seto, together with a part of their host gorgonacean *Anthogorgia bocki* (S. M. B. L., Type 161).

Description. Full-grown complete worm measures about 3 mm long and 0.18–0.24 mm wide for 38–42 setigerous segments. Body transparent, light orange, and flattened dorsoventrally in the anterior portion. Prostomium broader than long, with 2 pairs of small eyes. Median tentacle the longest, about 0.26 mm for 15 segments, more than four times the length of head. Lateral tentacles about half as long as median tentacle and 10–segmented. Palpi separate, though in close contact at base, not long. Dorsal peristomial tentacle about 0.5 mm long, longer than median tentacle and twice as long as ventral peristomial one.

Dorsal cirri on the anterior 1st to 6th segments are very elongate, multi-annulated; those on the succeeding 3 or 4 segments are shorter with 2–5 annulations. Of these the 1st cirri are the longest, of about 22–33 annulations and the following cirri are alternate in length, as shown in one example:

Body segment	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th	11th →
Number of annulations in dorsal cirri	33	7	7	15	6	10	5	3	3	3–1	1 …… 1

The remainder gradually diminish in size posteriorly and not annulated. Ventral cirri very minute all throughout, not extending beyond the end of parapodia. Each parapodium supported internally by a simple aciculum which is hooked at end; below

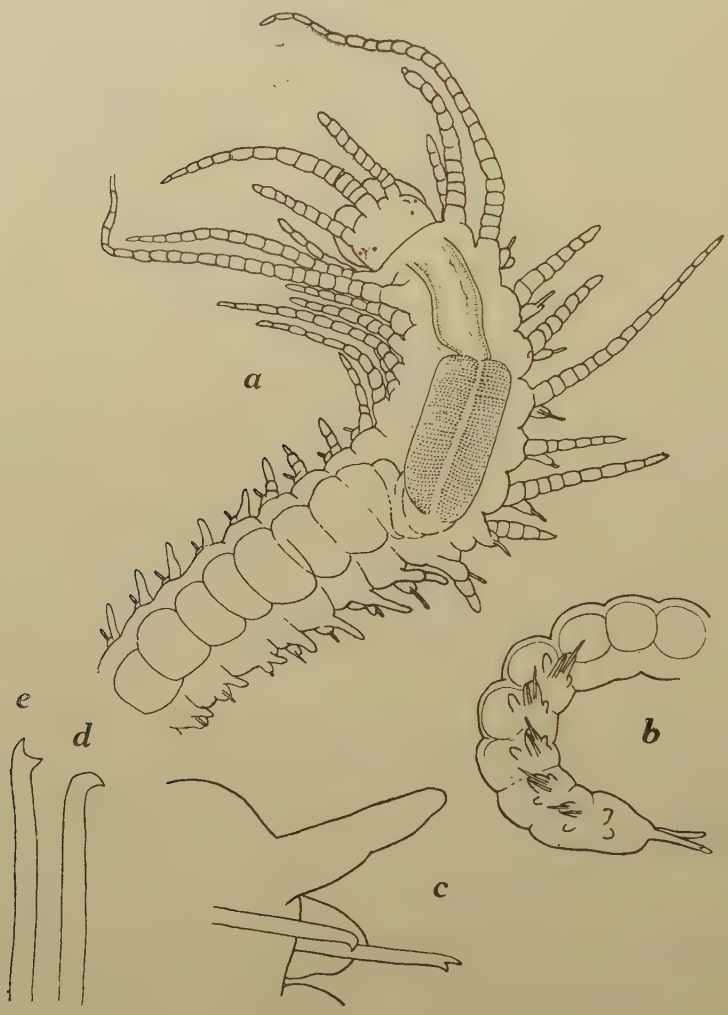


Fig. 2. *Haplosyllis anthogorgicola* sp. nov.
a, Anterior part of body, ×70; *b*, posterior part, ×70; *c*, parapodium, ×335; *d*, aciculum, ×510; *e*, seta, ×510.

there is on the outside only one simple seta with bidentate tip. Pygidium with 2 relatively long anal cirri.

In the fresh state, the alimentary tract is visible even through the body wall. Pharynx is thin-walled, about 0.33 mm long, runs through only three segments and

the next proventriculus of an enormous size, with strongly muscular walls, is approximately of the same length, extending through about four succeeding segments and 0.15 mm in diameter. It continues posteriorly to the annulated intestine of purplish orange color, running through the posterior segments, each bearing only a simple dorsal cirrus.

Remarks. This commensal syllid undoubtedly belongs to the genus (or subgenus of *Syllis*) *Haplosyllis* and is allied to the worldwide well-known *Haplosyllis spongicola* (GRUBE), living in association with sponges (FAUVEL, 1923, 1934). But it is distinctly different from the latter in the reduction of acicula and setae in the parapodia and the feeble development of dorsal cirri in the posterior setigerous segments. Such degeneration in structure is probably due to the permanent occurrence in tunnels or cavities formed beneath the bark of the gorgonacean. In other species of the genus *Anthogorgia*, we do not know still such a case of commensalism.

In connexion with this, it is to be noted that HICKSON (1940), in describing a muriceid gorgonacean *Versluysia ramosa* (THOMSON & HENDERSON) from the Indian Ocean, recorded the occurrence of *Syllis* (*Haplosyllis*) *spongicola* in association with a specimen taken from off Cape Guardafui, 37 meters. Although it is impossible to decide if the Indian "*Haplosyllis spongicola*" found on *Versluysia ramosa* is the same as this *H. anthogorgicola*, it is probably not the true *H. spongicola* living only in sponges.

Acknowledgment

In closing I must express my gratitude to Ass'nt. Prof. H. TSUKAHARA, of the Amakusa Marine Biological Station for the laboratory facilities during my stay and for the loan of a photograph reproduced in Pl. XXVII, fig. 1, and to Mr. K. MORIKAWA of the Ehime University for supplying me the collection of gorgonaceans.

LITERATURE

AURIVILLIUS, M. 1931. The gorgonaceans from Dr. S. BOCK's Expedition to Japan and Bonin Islands 1914. Kungl. Svenska Vetensk. Akad. Handl., Ser. III, 9 (4): 1–337, 6 pls.

BAYER, F. M. 1951. A revision of the nomenclature of the Gorgonidae (Coelenterata: Octocorallia), with an illustrated key to the genera. Journ. Wash. Acad. Sci., 41 (3): 91–102.

FAUVEL, P. 1923. Polychètes errantes. Faune de France, 5: 1–488. Paris.

———— 1934. Sur quelques syllidiens du Japon. Annot. Zool. Japon, 14 (3): 301–315.

GORDON, Is. 1926. Notes on a number of muriceid genera (Alcyonaria, Gorgonaceae), with special reference to spiculation. Proc. Zool. Soc. London, 1926 (2): 509–531, pl. 1.

HICKSON, S. J. 1930. On the classification of the Alcyonaria. Ibid., 1930: 229–252.

———— 1940. The Gorgonacea, with notes on two species of Pennatulacea. John Murray Exped., Sci. Rep., 6 (7): 267–317, pl. 1.

KÜKENTHAL, W. 1924. Gorgonaria. Das Tierreich, Lief. 47: xxviii+478 pp. Berlin u. Leipzig.

———— und GORZAWSKY, H. 1908. Japanische Gorgoniden. I Teil: Die Familien der Primnoiden, Muriceiden und Acanthogorgiiden. (Beitr. zur Naturg. Ostasiens, Herausgegeb.

von Dr. F. DOFLEIN.) Abh. math.-phys. Kl. K. Bayer. Akad. Wiss., I Suppl. Bd., Abh. 3: 1–71, 4 pls.

NUTTING, C. C. 1910. The Gorgonacea of the Siboga Expedition, III. The Muriceidae. Siboga Exped., Mono. 13b, Livr. 47, 108 pp., 22 pls. Leiden.

STIASNY, G. 1940. Gorgonaria aus dem Roten Meere. Sammlung Dr. Cyril Crossland, Ghardaqa, und der "Mabahith" Expedition 1934 5. Publ. Mar. Biol. Stat. Ghardaqa (Red Sea), 2: 121–192, pls. 1–10.

———— 1943. Die Gorgonarien-Familie Acanthogorgiidae Kükenth. & Gorz. mit besonderer Berücksichtigung des Materials der Siboga-Expedition. Zool. Anz., 141 (5/6): 127–133.

———— 1947. De Gorgonarien-Familie Acanthogorgiidae Kükenth. & Gorz. (Met bijzondere inachtneming van het materiaal der Siboga-Expeditie). Verh. Konin. Nederl. Akad. Wet., Afd. Natuurk., II, 43 (2): 1–93, pls. 1–3.

STUDER, Th. 1889. Supplementary report on the Alcyonaria collected by H. M. S. Challenger. Challenger Reports, Zool. 32 (81): 1–31, pls. 1–6.

THOMSON, J. A. and DEAN, L. M. I. 1931. The Alcyonacea of the Siboga Expedition, with an addendum to the Gorgonacea. Siboga Exped., Mono. 13d, Livr. 115, 227 pp., 28 pls. Leiden.

———— and HENDERSON, W. D. 1906. An account of the alcyonarians collected by the Royal Indian Marine Survey Ship "Investigator" in the Indian Ocean. I, The alcyonarians of the deep sea. xvi+132 pp., 10 pls. Calcutta.

———— and SIMPSON, J. J. 1909. Alcyonaria of the "Investigator." II, The Alcyonaria of the littoral area. xii+319 pp., 9 pls. Calcutta.

VERRILL, A. E. 1868. Critical remarks on the halcyonoid polyps in the Museum of Yale College, with descriptions of new genera. Amer. Jour. Sci. and Arts, II, 45: 411–415.

———— 1869. Synopsis of the polyps and corals of the North Pacific Exploring Expedition, etc. Additions and corrections. Proc. Essex Inst., 6: 41–48.

EXPLANATION OF PLATE XXVII

Fig. 1. Dry specimen of *Anthogorgia bocki* AURIVILLIUS from Tomioka (courtesy Mr. H. TSUKAHARA). ×1/6.

Fig. 2. Dry specimen of *Anthogorgia bocki* AURIVILLIUS from Seto. ×1/9.

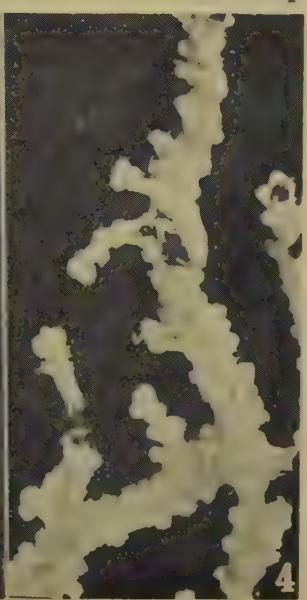
Fig. 3. Specimen wholly covered with bark from Kii-ôsima. ×1/3.

Fig. 4. Part of branches of a living specimen from Seto, slightly magnified. ×5/3.

1

2

3



4

THE PELAGIC COPEPODS OF THE IZU REGION, MIDDLE JAPAN SYSTEMATIC ACCOUNT I.

FAMILIES CALANIDAE AND EUCALANIDAE

Otohiko TANAKA
Fisheries Department, Faculty of Agriculture, Kyushu University

With 5 Text-figures

The report had in the original manuscript the following contents: Introduction, Material and method, List of stations and date of collection, List of species, Systematic account, Zoogeographical and vertical distribution of the species, and Reference list. The first three chapters have been published in the journal "Records of Oceanographic Works in Japan, New Series, vol. I, no. 1, pp. 124–137, 1955." The present paper deals only with the Systematic account and forms Part I of the series which will be appeared continually in this journal. The present study was completed in 1948, but owing to publication difficulties the appearance of the paper was delayed much.

Systematic Account

Family CALANIDAE

Genus *Calanus* Leach, 1819

The genus *Calanus* (sensu lato) has often been reduced by the separation of a number of species to other genus. At present the following genera are represented in the family Calanidae: *Calanus* Leach, *Calanoides* Brady, *Canthocalanus* A. Scott, *Neocalanus* G. O. Sars, *Megacalanus* Wolfenden, *Bathycalanus* G. O. Sars, *Undinula* A. Scott and *Nannocalanus* G. O. Sars.

These genera resemble so closely one another in general appearance that some of the authors still include them in the genus *Calanus*. *Calanus finmarchicus* (Gunnerus) is regarded as the type of the genus *Calanus*. The generic characteristics of *Calanus* in the restricted sense are as follows: Head is, in most cases, separate from the 1st thoracic segment; the 4th is separate from the 5th; the rostrum consists of two slender filaments; the 1st antenna and mouth parts are of normal structure; the 1st to 4th legs with 3-jointed exopodite and endopodite; the distal joint of the exopodite of the 1st to 4th legs with two outer marginal spines; the male 5th pair of legs have general

resemblance to those of the female, but the left leg is slightly modified in shape and armature.

Six species belonging to the genus *Calanus* (sensu stricto) have been recorded from the neighbouring waters of Japan: *C. finmarchicus* (GUNNERUS), *C. hyperboreus* KRÖYER, *C. tenuicornis* DANA, *C. cristatus* KRÖYER, *C. minor* (CLAUS) and *C. plumchrus* MARUKAWA. The last one has been reported from the northern water and is very closely allied to *C. tonsus* BRADY, some author distinguishes the species from the typical *tonsus* under a variety name, *C. tonsus* var. *plumchrus*. *C. hyperboreus* KRÖYER has been recorded from the Japan Sea by MARUKAWA, but I have not met with the species in the Izu region.

Calanus finmarchicus (GUNNERUS)

(Fig. 1, *a–j*)

C. finmarchicus GIESBRECHT, 1892, p. 89, t. 6, 7, 8; G. O. SARS, 1903, p. 11, pl. 4; ESTERLY, 1905, p. 125; WITH, 1915, p. 10; FARRAN, 1929, p. 212; WILSON, 1932, p. 23; *C. helgolandicus*, WILSON, 1932, p. 25; *C. finmarchicus*, JESPERSEN, 1934, p. 10; MORI, 1937, p. 13, pl. 2; *C. helgolandicus*, MORI, 1937, p. 14, pl. 1; *C. finmarchicus* SEWELL, 1947, p. 13; MARSHALL and ORR, 1955, p. 1; *C. helgolandicus*, MARSHALL and ORR, 1955, p. 4.

It has been noticed by many authors that there are two size groups in *C. finmarchicus*. According to SARS the large specimen is *C. finmarchicus*, and the small specimen *C. helgolandicus*. The size given by the authors are as follows:

	Female, Length (mm)	Male, Length (mm)
GIESBRECHT ·····	2.7–4.5	2.35–3.2
G. O. SARS ·····	about 4.0	3.60
	(about 3.0	2.80 *helgolandicus*)
WITH ·····	2.8–5.5	3.0–4.0
FARRAN ·····	2.64–3.2	
JESPERSEN ·····	3.5–4.5 (large size)	
	2.4–4.5 (small size)	
MORI ·····	about 4.0–5.0	about 3.6
	(about 3.0	about 2.8 *helgolandicus*)

The specimen of the Izu region measured:

3.5–4.07 (large size)	3.0–3.7
2.38–3.10 (small size)	2.45–2.80

SARS (1903) described a species of *Calanus* which he thought to be identical with the specimen reported by CLAUS under the name *Cetochilus helgolandicus*. He pointed out that the specimen differs from *C. finmarchicus* in its size, the proportional length of the furcal ramus, and in the structure of the male 5th legs.

The specimens of the Izu region, so far as I have examined, can be divided into

two size groups. These forms are found commonly in the surface and intermediate layers. The large form has the forehead more evenly rounded; the proportional lengths of the metasome to urosome 3.8 : 1; the furcal rami about 1.3 times as long as wide. In the small form the head is more produced and narrowly rounded; the proportional lengths of the metasome to urosome are 3.6 : 1; the furcal rami about 1.4 times as long as wide. The male of the small form has the left 5th leg with a

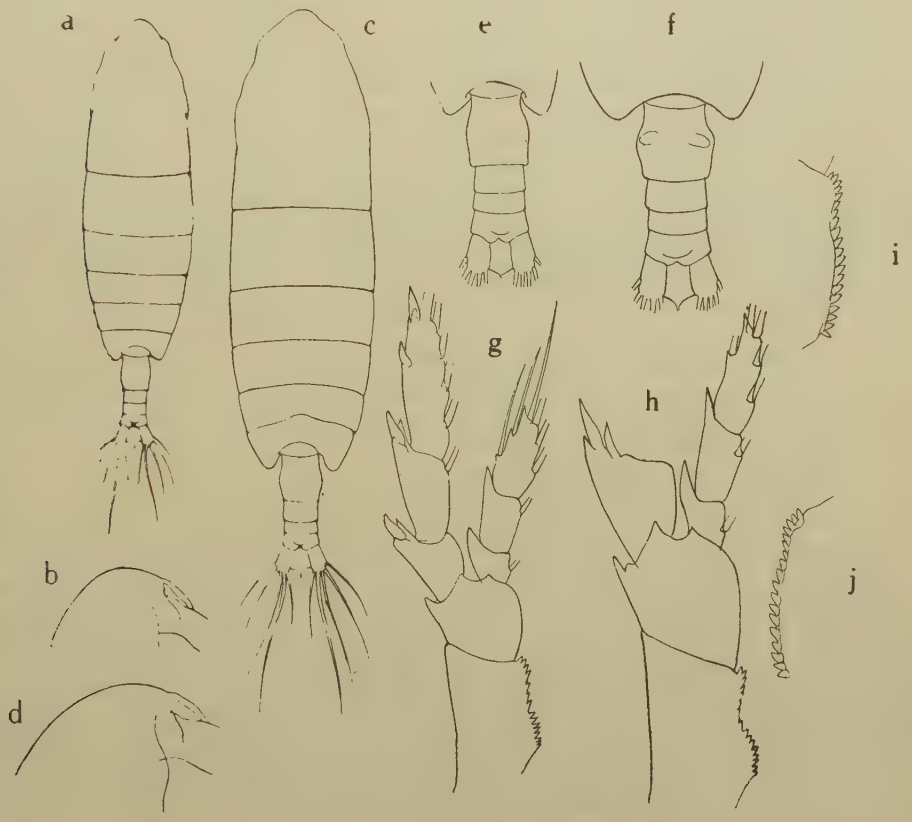


Fig. 1. *Calanus finmarchicus* (GUNNERUS).

a, Female: small specimen, dorsal aspect; *b*, head, lateral aspect; *c*, large specimen, dorsal aspect; *d*, head, lateral aspect; *e*, abdomen, dorsal (specimen 2.4 mm); *f*. abdomen, dorsal (specimen 2.9 mm); *g*, 5th leg (2.4 mm); *h*, 5th leg (2.9 mm); *i*, left inner margin of 1st basal joint of 5th leg (3.78 mm); *j*, right inner margin of 1st basal joint of 5th leg (3.78 mm).

slender exopodite than that of the large form. These differences are quite similar to those found in the specimens of the Europian waters. One could have, if he wishes, regarded the small form as *C. helgolandicus*, and the large as *C. finmarchicus*. MARSHALL and ORR (1955) report that there are two forms also in the Plymouth and Clyde sea area, though *helgolandicus* is larger than *finmarchicus* in those areas.

It has been reported that the size of *C. finmarchicus* shows a remarkable regional and seasonal variation. According to BOGOROFF the copepods grow larger in cold waters than in the warm. He shows as an example:

Locality	Average total length (mm)	Temperature °C
69°30′ N–75°N	3.22	4.6
75° N–77°N	3.78	1.08
North of 77°N	4.57	

JESPERSEN gives the following example:

Eastern North Sea	ca. 1.9–2.7 mm
West Greenland water	2.4–4.5

RUSSELL (1935) shows that in Plymouth area there are three main breeding seasons, and each brood differs in size. The individuals of the first brood during the cold period of the year grow to the largest, thereafter the remaining broods decrease in size as the temperature rises. The seasonal variation in size of the adult in the Izu region are as follows:

Month	Total length (mm)	
	Female	Male
December, 1936	2.38–3.01	2.56–2.98
February, 1937	3.75–3.86	
March, 1937	3.65–3.80	
April, 1937	4.03	3.49–3.70
June, 1937	2.80–2.90	

These two forms have each different habit in the vertical distribution; the small predominates in the upper layer down to 200 m, whereas the large in the layer deeper than 200 m; the immature specimens of the large form were found below 400 m in the month October 1937. The temperature of the 200 m layer was about 12°C, and that of the 400 m was about 8°C respectively. MORI reported that he has obtained only a single specimen of *C. finmarchicus*, but plenty of *helgolandicus* from Japanese waters. It can be attributed to the fact that he has collected only in the upper layer less than 200 m in the warm sea area.

As above mentioned, *C. finmarchicus* varies in size according to the conditions of life. The proportional lengths of the metasome to urosome show some individual difference. But there are some minute points of difference between these two forms. For instance, the inner margin of the 1st basal joint of the 5th legs of the female is straight or slightly convex in *finmarchicus*, whereas it is concave in *helgolandicus*. These two forms are, indeed, distinguishable, but there is no sufficient ground to raise the small form to the rank of species. Here I propose to separate the specimen with produced head from the specimen with evenly rounded head under a variety name *C. finmarchicus* var. *helgolandicus*.

Female. Length, large form, 3.50–4.07 mm. The abdomen is contained 3.6–4.1

times in the length of the cephalothorax; the genital segment is wider than long (36 : 32); the furcal rami about 1.3 times as long as wide (16 : 12); the 1st antenna extends to the end of the furca; the inner margin of the 1st basal joint of the 5th leg had is straight or slightly convex, and had 20 to 22 teeth.

The small form measured 2.38–3.10 mm; the cephalothorax narrow when viewed from the dorsal; the head is more produced; the abdomen is contained 3.5–4.2 times in the length of the cephalothorax; the genital segment is longer than wide (23 : 21–22); the furcal rami 1.4 times as long as wide (11 : 8); the 1st antenna exceeds the end of the furca by terminal two joints; the inner margin of the 1st basal joint of the 5th leg is straight or slightly concave, and had 14 to 22 teeth. The small specimen measured 2.90 mm had only five setae on the distal joint of endopodite of 5th pair of legs.

Male. Length. The large form, 3.49–3.70 mm; the small form, 2.50–2.98 mm; both forms have the 5th pair of legs of the similar structure except that the small form has the exopodite in the right leg reaching the proximal one-third of the 2nd joint of the exopodite of the left leg, whereas the large has the exopodite reaching the middle of the 2nd joint of the exopodite of the left leg.

Occurrence. Two forms are found commonly in the Izu region. The small form abundant in the upper layer, and the large predominates in the deeper layers.

Distribution. The species has a wide distribution in all oceans.

Calanus tenuicornis (DANA)

Calanus tenuicornis GIESBRECHT, 1892, p. 90. t. 6, 7, 8; A. SCOTT, 1909, p. 9; FARRAN, 1929, p. 217; SEWELL, 1929, p. 20; FARRAN, 1936, p. 77; MORI, 1937, p. 16, pl. 3, 4; VERVOORT, 1947, p. 22.

SARS included this species along with *C. gracilis* DANA and *C. robustus* GIESBRECHT in his proposed genus *Neocalanus*. But the absence of the hook on the 2nd basal joint of the 1st leg, and the fact that the head and the 1st thoracic segment are separate in this species, whereas in *gracilis* and *robustior* they are fused, are the sufficient grounds for separating the present species from the other too.

Length. Female, 1.99–2.10 mm. Male, 1.77 mm.

Occurrence. Three adult female and two males in a vertical haul from the depth 1000 m to the surface in Suruga Bay. The species appears to be rather a deep water species. It has been seldom obtained from the surface in the Izu region.

Distribution. The species is widely distributed in the tropical and subtropical regions of the Pacific, Atlantic and Indian Oceans.

Calanus plumchrus MARUKAWA

(Fig. 2, *a–d*)

C. plumchrus MARUKAWA, 1921, p. 10, pl. 1; *C.* sp. SATO, 1913, p. 3, pl. 2.
C. tonsus CAMPBELL, 1930, p. 177; TANAKA, 1954, p. 29, figs. 1–4.

C. tonsus MARSHALL and ORR, 1955, p. 8.
C. plumchrus TANAKA, 1956, p. 49, figs. 1–4.

Calanus tonsus BRADY was described by BRADY from the material taken in the southeast coast of the Australia (lat. 34°8′) and the east coast of South America (lat. 42°43′ S.). The species was also recorded by BRADY between Yokohama and Sandwich Island (Lat. 35°41′ N.). FARRAN recorded the species at stations off New Zealand between lat. 30°–40° S. and lat. 50°–60° S. WILSON recorded it from the

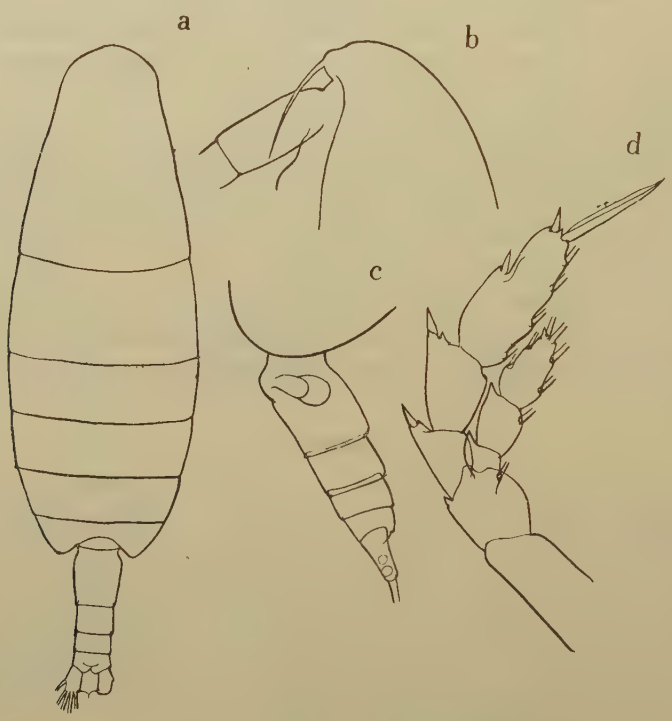


Fig. 2. *Calanus plumchrus* MARUKAWA.
a, Female, dorsal aspect; *b*, head, lateral aspect; *c*, abdomen, lateral aspect; *d*, 5th leg,

Woods Hole region. The occurrence of the species in the northern Pacific was reported by JOHNSON (1932), CAMPBELL (1934), TANAKA (1954), VINOGRADOV (1955), and BRADSKY (1955).

Recently Mr. J. NAKAI of the Tôkai Regional Fisheries Laboratory has informed me by personal communication that the original specimen of *C. tonsus* BRADY is not identical with the specimen from the northern Pacific. He says that the specimen from the southern hemisphere is smaller in size, and has the 2nd to 5th swimming legs which are furnished with small spines on the inner distal margin of the 2nd

basal joint; the proportional lengths of the proximal and distal outer margin of the 3rd joint of the exopodite divided by the outer marginal spine in the 2nd to 4th legs are different from those found in the northern specimen. These characters were mentioned by F. DAHL (1894) and by N. WOLFENDEN (1908) but not by BRADY. He must have overlooked these characters or examined the specimen which has no such characters. Accordingly there are forms in *C. tonsus* BRADY. In my previous paper I have made no distinction between the northern and southern specimens. Russian zoologists are of opinion that these forms are not distinct. MARSHALL and ORR (1955) distinguished the northern form from the southern one under a variety name *C. tonsus* var. *plumchrus*, but it is not clear upon whose reference they have made the distinction. NAKAI insists on the validity of *C. plumchrus* MARUKAWA. Recently I had an opportunity to examine the Antarctic specimen of *C. tonsus* BRADY. On comparing the specimen with that of the North Pacific, these two specimens are not identical. The specimen of the Antarctic is *C. tonsus* BRADY, and the specimen from the North Pacific is *C. plumchrus* MARUKAWA.

Female. Length, 4.83–6.32 mm; cephalothorax, 3.75 mm; abdomen, 1.08 mm; so the abdomen is contained 3.5 times in the length of the cephalothorax. The head separates from the 1st thoracic segment; the lateral corners of the last thoracic segment rounded; the rostrum with two long and slender filaments.

The abdomen 4-segmented, the joints and furca in the proportions 42 : 18 : 10 : 10 : 20 = 100; the genital segment inflated at the proximal lateral margins; it is slightly longer than wide (42 ; 39) ; the furcal rami 2-times as long as wide.

The 1st antenna broken off in the distal joints; specimen measuring 5.90 mm had the joints in the proportional length in 0.01 mm:

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
30	27	15	16	18	18	19	15	15	20	21	27	27	30	34	35	35	33.

The 2nd antenna has the endopodite about as long as the exopodite (50 : 48). The mandible has the exopodite 1.4 times as long as the exopodite (20 : 14). In the 1st maxilla the 1st inner lobe has no setae; the 2nd lobe has one or two setae; the 3rd has four long setae; the 1st outer lobe has six long setae and one short spine; the exopodite has ten setae; the distal joint of the endopodite has six setae, the 2nd joint has and 1st joint of the endopodite has four setae respectively; the 2nd basal joint has four setae. The 2nd maxilla feeble. The maxillipede soft-skinned and fairly reduced.

The 1st to 5th legs have each 3-jointed exopodite and endopodite. The outer margin of the distal joint of the exopodite of the 2nd and 4th legs is divided by the outer marginal spine into the proportional lengths 20 : 20, 26 : 21. The 5th leg has no inner marginal seta on the 1st basal joint, and the inner margin of the joint smooth; the distal joint of the endopodite bears six marginal setae; the outer margin of the 3rd joint of the exopodite is divided by the outer marginal spine in the proportional lengths 19 : 14.

Male. Length, 4.40–4.82 mm; the male specimen was fully described in my previous paper.

Remarks. The present specimens are larger in size than *C. tonsus* BRADY originally described by BRADY (3.60 mm). FARRAN's specimen from the South Atlantic measured 3.48–3.60 mm, and has the lateral margins of the genital segment of the female, when viewed from the dorsal is more inflated than those of the present specimen (FARRAN, 1929, fig. 12).

Occurrence. Twenty females in the vertical hauls from 1000 m to the surface in Sagami Bay, November 1937. The adult mole and female have been collected also from the deep waters of the Japan Sea.

Distribution. The northern form is widely distributed in the North Pacific. The adult specimen was found in Japanese waters from the deep layers of the Pacific and the Sea of Japan.

Calanus cristatus KRÖYER

Calanus cristatus GIESBRECHT, 1892, p. 91, t. 6; VAN BREMEN, 1906, p. 10; WITH, 1915, p. 11; MORI, 1937, p. 15; TANAKA, 1938, p. 599, fig. 1, 2.

The adult specimens, both female and male, have been obtained from the deep water of Sagami Bay in October 1938. Dr. M. W. JOHNSON informed me that he had also taken the adult specimens in the cold water of the North Pacific. The immature specimens has been reported from the surface water of northern Japan. The immature specimens were found in Sagami Bay from the intermediate layers between 300–500 m, whereas the adult from the depth more than 500 m.

Calanus hyperboreus KRÖYER

Calanus hyperboreus GIESBRECHT, 1892, p. 91, t. 6, 7, 8; G. O. SARS, 1903, p. 12; MARUKAWA, 1928, p. 21; WILSON, 1932, p. 21, fig. 8; JESPERSEN, 1934, p. 34.

The species has been recorded from the northern waters of the Atlantic. MARUKAWA recorded its occurrence from the Japan Sea, but it seems to be doubtful. According to SARS, the species has been found occasionally off the Finmark coast and Lofoten Island, together with *Calanus finmarchicus*, but further southwards it appears to be wholly restricted to the great depth of the fjords. WILSON records it from the Woods Hole region and the Gulf of Maine, and further south to the Gulf Stream in winter season. JESPERSEN recorded it from the Davis Strait and Baffin Bay.

Calanus minor (CLAUS)

Calanus minor GIESBRECHT, 1892, p. 33, t. 6, 7, 8; ESTERLY, 1905, p. 126; A. SCOTT, 1905, p. 7; *Nannocalanus minor* G. O. SARS, 1925, p. 9; SEWELL, 1929, p. 20; *Calanus minor*

WILSON, 1936, 2, p. 22; FARRAN, 1936, p. 77; MORI, 1937, p. 17, pl. 5; *Nannocalanus minor*, VERVOORT, 1947, p. 26.

This species of *Calanus* has been transferred to the genus *Nannocalanus* by G. O. SARS by the fact that the head is fused with the 1st thoracic segment, and by the structure of male 4th pair of legs which differ from those of the typical *Calanus*. SEWELL recorded two forms, differing each other only in size, from the Indian waters.

Length. Female, 1.77–1.84 mm. Male, 1.50–1.56 mm.

Occurrence. The species is not so common in the Izu region. A vertical haul from 1000 m to the surface in Suruga Bay contained three adult females.

Distribution. The species has a wide distribution in the tropical and subtropical regions of the Pacific, Atlantic and Indian Oceans. In Japan it has been recorded from warm currents.

Genus *Calanoides* BRADY, 1883

The genus was separated from the typical *Calanus* by the possession of prehensile structure in the male 5th legs, and in having 4 marginal setae in the terminal joint of the endopodite of 5th leg of the female. The genus is represented by three species, *Calanoides carinatus* KRÖYER (=*brev.* LUBBOCK), C. *pathagoniensis* BRADY and *C. acutus* GIESBRECHT. One of them occurred in the present collection.

Calanoides carinatus KRÖYER

Calanus brevicornis GIESBRECHT, 1892, p. 90, t. 6, 7, 8; *Calanoides brevicornis* A. SCOTT, 1909, p. 10; TANAKA, 1937, p. 251, fig. 1; *C. carinatus* VERVOORT, 1947, p. 29, figs. 1–3.

The specimen collected was an immature female, measuring 2.75 mm. The species has been recorded from the Malayan region by A. SCOTT. CLEVE recorded it from the Indian Ocean but SEWELL failed to detect it in the "Investigator" collection.

Genus *Canthocalanus* A. SCOTT, 1909

This genus was created by A. SCOTT to accomodate a species which differs from the typical *Calanus* in the peculiar structure of the 2nd basal joint of the 1st leg, and the characters of the male 5th legs. The hook is observed on the 2nd basal joint of the 1st leg of the following four species: *Canthocalanus pauper* (GIESBRECHT), *Calanus robustior* (GIESBRECHT), *Calanus gracilis* (DANA) and *Megacalanus princeps* (WOLFENDEN). According to A. SCOTT, the hook on the 2nd basal joint of the 1st leg of *Canthocalanus* is quite different from that of the other three species, *viz.*: the

2nd joint is furnished with a strong, naked pyriform spine on its anterior surface; the base of this spine is only slightly attached to the surface of the joint; a considerable portion of the spines is continued upward into a distinct tooth-like process, resulting with the combination of the hook on the 1st joint, in the formation of a feeble prehensile apparatus. Further he states on the hook which is found in the 2nd basal of the 1st legs of *Megacalanus*: "This hook is quite distinct from that found in *Canthocalanus*. In *Megacalanus* the hook is a well-defined projection from the surface of the joint, and has a plumose seta articulated to it. In *Canthocalanus* the seta is transformed into a strong spine with a hooked base." A. SCOTT further emphasizes as a characteristic of *Canthocalanus* on the naked rudimentary 3-jointed endopodite of the left 5th leg of the male but this rudimentary endopodite is observed also in the left 5th leg of *Calanus robustior* GIESBRECHT. Were it sufficient reasons proposed by A. SCOTT to separate the genus *Canthocalanus* from the typical *Calanus* that the species of *Canthocalanus* has a hook and a strong spine on the 2nd basal of the 1st leg of the female, and naked endopodite on the left 5th leg of the male, one could have well transferred *Calanus robustior* into the genus *Canthocalanus*. A. SCOTT, however, included *Calanus robustior* and *C. gracilis* in the genus *Megacalanus* only on the ground that these three forms have a similar hook on the 2nd basal of the 1st leg. But he does not care the fact that in the female of *Calanus robustior* and *C. gracilis*, the head and the 1st thoracic segment are fused, and the distal spine of the terminal joint of the exopodite of the 1st leg is of peculiar shape, whereas in *Megacalanus* the head and the 1st thoracic segment are separate. Moreover, in *Megacalanus*, the distal joint of the exopodite of 2nd to 4th leg has three outer marginal spines, and the terminal spine of the 3rd joint of the exopodite of the 1st leg is of usual structure.

It seems unreasonable, as cited above, that A. SCOTT has included *C. robustior* and *C. gracilis* in the genus *Megacalanus*. They should be transferred to other genus. It is advisable to keep them in the genus *Neocalanus* proposed by G. O. SARS.

Canthocalanus pauper (GIESBRECHT)

Calanus pauper GIESBRECHT, 1892, p. 91, t. 6, 8; *Canthocalanus pauper* A. SCOTT, 1909, p. 9; *Calanus pauper* FARRAN, 1929, p. 215; *Canthocalanus pauper* SEWELL, 1929, p. 25; *Calanus pauper* FARRAN, 1936, p. 77; MORI, 1937, p. 18, pl. 6; *Canthocalanus pauper*, VERVOORT, 1947, p. 36.

Length. Female, 1.48–1.62 mm. Male, 1.40 mm.

Occurrence. The species is rare in the Izu region. Only two adult females and one male have been collected from the surface layer.

Distribution. The species has been recorded from the tropical and subtropical regions of the Pacific and Indian Oceans. In Japanese waters it has been recorded from the warm currents.

Genus *Neocalanus* G. O. Sars, 1925

Calanus robustior Giesbrecht and *C. gracilis* Dana have been often transferred from one genus to another by different authors. A. Scott accomodated them in the genus *Megacalanus* Wolfenden on the ground that they have strong hook on the 2nd basal joint of the 1st leg. But he does not mention the absence of the peculiar terminal spine on the exopodite of the 1st leg. Sars separated these two species from the genus *Megacalanus* by the fact that in these two species the head and the 1st thoracic segment are fused, and by the features of the male 5th legs. He included these species along with *C. tenuicornis* Dana in his proposed genus *Neocalanus* without paying any attention to the presence of a strong hook on the 2nd basal joint of the 1st leg in *C. robustior* and *C. gracilis*. If it were Sars' main reason for including *C. tenuicornis* in the genus *Neocalanus* that it has the similar structure in the male 5th pair of legs to those of *robustior* and *gracilis* we had better accomodate *C. robustior* in the genus *Canthocalanus* and *A. gracilis* in the typical *Calanus*. However, the female specimen of *robustior* and *gracilis* have the similar structure in the 1st leg, and the same number of segments in the cephalothorax which differ from that of *C. tenuicornis*. It is advisable to remove *C. tenuicornis* from the genus *Neocalanus*, and keep it in the typical *Calanus*.

Neocalanus gracilis (Dana)

Calanus gracilis Giesbrecht, 1892, p. 90, t. 1, 6, 7, 8; *Megacalanus gracilis*, A. Scott, 1909, p. 12; *Neocalanus gracilis* G. O. Sars, 1925, p. 7; *Calanus gracilis* Farran, 1929, p. 217; *Neocalanus gracilis* Sewell, 1929, p. 26; Wilson, 1932, p. 28; *Calanus gracilis* Mori, 1937, p. 16, pl. 3, 4; *Neocalanus gracilis*, Vervoort, 1947, p. 40.

Length. Female, 2.95–3.25 mm.

Remarks. The male of this species has the 1st thoracic segment separated from the head, and the 5th pair of legs which resemble of *C. tenuicornis* Dana, but the 1st basal joint of the left 5th leg is longer than that of the right, and the exopodite of the left leg much elongated.

Occurrence. The species is rather rare in the Izu region. It was collected by the vertical hauls from 1000 m to the surface in Sagami and Suruga Bay.

Distribution. The species has been recorded from the tropical and subtropical regions of the Pacific, Atlantic and Indian Oceans.

Neocalanus robustior (Giesbrecht)

Calanus robustior Giesbrecht, 1892, p. 91, t. 7, 8; Esterly, 129; *Megacalanus robustior* A. Scott, 1909, p. 13; *Neocalanus robustior* G. O. Sars, 1925, p. 8; *Calanus robustior* Farran, 1929, p. 217; Mori, 1937, p. 17, pl. 3, 4; *Neocalanus robustior*, Vervoort, 1947, p. 44.

Length. Male, 3.00 mm.

Remarks. The male specimen has the 1st thoracic segment which is separated from the head. The left 5th leg of the male resembles that of *Canthocalanus pauper* in having a rudimentary 3-jointed endopodite.

Occurrence. The species is very rare in the Izu region. A single male specimen was obtained in a surface haul at Misaki in winter of 1930.

Distribution. The species has been recorded from the tropical and subtropical regions of the Pacific, Atlantic and Malay Archipelago. In Japan, it has been recorded from the warm currents.

Genus *Megacalanus* WOLFENDEN, 1904

The genus was established by WOLFENDEN in 1904 to accomodate a large copepod which he obtained from the deep water of the Atlantic, and called it *Megacalanus princeps*. The genus is distinguished from the typical *Calanus* in having a remarkable hook on the anterior surface of the 2nd basal joint of the 1st leg, and the presence of three outer marginal spines on the 3rd joint of the exopodite of the 2nd to 4th legs. In the same year SARS described the same species under the name *Macrocalanus longicornis*. WOLFENDEN (1905) added a second species of *Megacalanus* which he considered to be identical with *Calanus princeps* BRADY. So the specific name of the first form, *M. princeps*, was renamed *M. bradyi* and the name *M. princeps* was applied to the second form which is clearly not *Megacalanus*. A. SCOTT (1909) created a new genus *Bradycalanus*, and suggested that *Calanus princeps* BRADY may probably belong to his proposed genus. SARS, however, included *Bradycalanus* into *Megacalanus* on the ground that these genera differ only in the presence or absence of a hook on the 2nd basal joint of the 1st leg. The genus *Megacalanus* proposed by SARS is, at present, generally accepted, and the genus comprises three species: *M. princeps* WOLFENDEN, *M. sarsi* FARRAN, which is identical with *Macrocalanus princeps* SARS 1905, and *M. typicus* (A. SCOTT). One of them appeared in the collection.

Megacalanus princeps WOLFENDEN

(Fig. 3, *a-d*)

Megacalanus princeps A. SCOTT, 1909, p. 13, pl. 1; *M. longicornis* SARS, 1925, p. 14, pl. 3; SEWELL, 1929, p. 27; *M. princeps* VERVOORT, 1947, p. 49, fig. 4.

Female. Length, 10.34 mm; cephalothorax, 18.15, abdomen, 2.19 mm; the cephalothorax elongate ovate; the lateral corners of the last thoracic segment triangularly produced; the rostrum consists of two strong spines.

The abdomen 4-segmented; the segments and furca in the proportions 41 : 20 : 15 : 7 : 17 = 100; the furcal rami slightly longer than wide.

The 1st antenna 25–jointed, exceeds the end of the furca by terminal nine joints. The mouth parts as those of the genus *Calanus*. The maxillipede is furnished with stiff hairs on the middle part of the 1st basal, and on the proximal half of the 2nd basal joint.

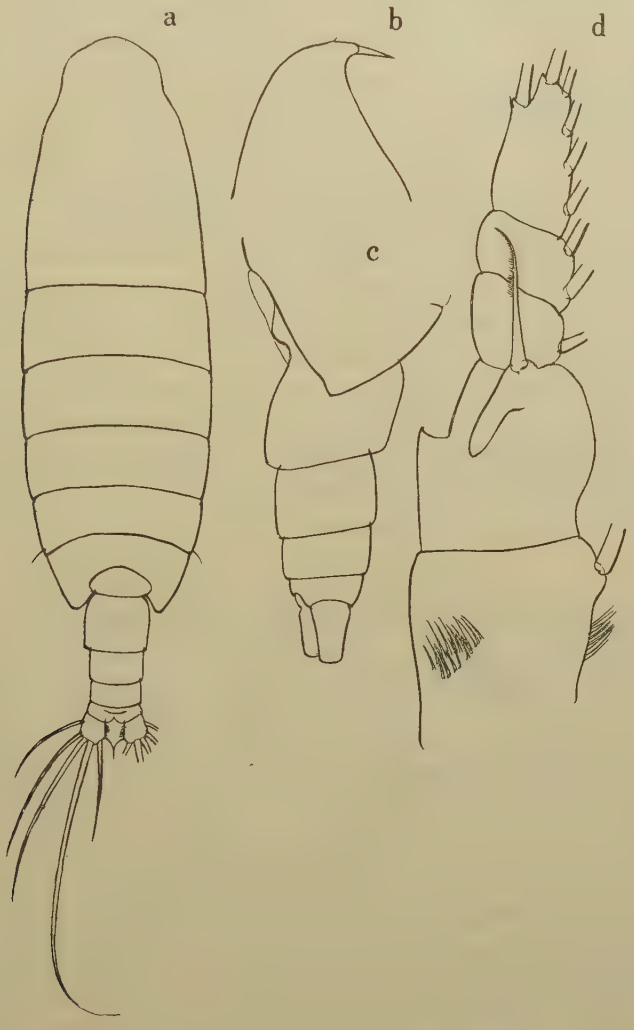


Fig. 3. *Megacalanus princeps* WOLFENDEN.
a, Female, dorsal aspect; *b*, head, lateral aspect; *c*, last thoracic segment and abdomen, lateral aspect; *d*, basal joints and endopodite of 1st leg.

The 1st to 5th legs have each 3–jointed exopodite and endopodite. There is a prominent hook on the 2nd basal joint of the 1st leg at the junction with the endopodite. The outer margin of the 3rd joint of the exopodite of the 2nd to 4th legs has

three spines. The 5th leg has two outer marginal spines on the 3rd joint of the exopodite.

Remarks. *Pseudolovenula magna* MARUKAWA is, according to VERVOORT, identical with the present species.

Occurrence. Five female specimens from the deep waters of Sagami and Suruga Bay.

Distribution. The species has wide distribution in the deep waters of the Pacific, Atlantic, and Indian Oceans.

Genus *Bradycalanus* A. SCOTT, 1909

A. SCOTT created the genus *Bradycalanus* to accomodate the species which resembles closely *Megacalanus* WOLFENDEN. His genus is distinguished from the latter by the densely plumose spine on the apex of the 2nd maxilla, and by the absence of the hook on the anterior surface of the 2nd basal joint of the 1st leg. The other appendages are as those in *Megacalanus*. SARS merged the genus *Bradycalanus* into *Megacalanus* in his monograph of 1925. The genus *Bradycalanus* is represented by a single species *B. typicus* A. SCOTT. VERVOORT recorded the species in the Snellius Expedition under the name *Megacalanus typicus*. No example of the genus has been met with in the present collection.

Genus *Bathycalanus* G. O. SARS, 1905

The genus was created by SARS to accomodate a single species, *B. richardi*, which was obtained from the Atlantic. The genus *Bathycalanus* differs from *Megacalanus* WOLFENDEN in the peculiar armature of the frontal part of the head, and in the structure of the maxillae and maxillipede, and the 1st pair of legs. The 1st leg has no hooked process on the 2nd basal joint, and the exopodite is composed of two joints.

At present three species, *B. richardi* SARS, *B. bradyi* WOLFENDEN (=*Megacalanus bradyi* WOLFENDEN, 1905) and *B. princeps* (BRADY) (=*Calanus princeps* BRADY, 1883) have been reported. SEWELL recorded *B. richardi* SARS from the Indian Seas. VERVOORT recorded three species in the Snellius Expedition. But no example of the genus has been met with in the Izu region.

Genus *Undinula* A. SCOTT, 1909

The genus was named by A. SCOTT to accomodate some species of *Calanus* which exhibit a considerable difference in the structure of the male 5th pair of legs. The female of the genus differs very little in the structure of the appendages from typical *Calanus*. The genus, at present, comprises two species, *U. darwini* (LUBBOCK) and *U. vulgaris* (DANA). Both of them appeared commonly in the Izu region.

Undinula darwini (LUBBOCK)

Calanus darwini GIESBRECHT, 1892, p. 91, t. 6, 7, 8; *Undinula darwini* A. SCOTT, 1909, p. 17; FARRAN, 1929, p. 217; SEWELL, 1929, p. 42; FARRAN, 1936, p. 78; *Calanus darwini*, MORI, 1937, p. 18, pl. 5; *Undinula darwini*, VERVOORT, 1947, p. 77.

Length. Female, 2.13–2.56 mm. Male, 1.93–2.1 mm.

Remarks. SEWELL divided the female specimen into three forms: forma *typica*, forma *typica* var. *symmetrica*, and forma *typica* var. *intermedia*; the present specimen is identical with forma *typica*, but the posterior margin of the thoracic segment is not produced on the right side as figured by SEWELL.

Occurrence. The species is one of the most common surface-living one in the Izu region.

Distribution. The species is widely distributed in the warm waters of the Pacific, Atlantic and Indian Oceans.

Undinula vulgaris (DANA)

Calanus vulgaris GIESBRECHT, 1892, p. 92, t. 6, 7, 8; *Undinula vulgaris* A. SCOTT, 1909, p. 18; *Calanus vulgaris* FARRAN, 1929, p. 216; *Undinula vulgaris* SEWELL, 1929, p. 81; WILSON, 1932, p. 29; FARRAN, 1936, p. 77; *Calanus vulgaris* MORI, 1937, p. 19, pl. 5, 6; *Undinula vulgaris* VERVOORT, 1947, p. 72.

Length. Female, 2.75–2.81 mm. Male, 2.31–2.69 mm.

Remarks. MORI (1937) recorded an abnormal specimen with branched furcal setae which had previously been described as *Calanus orientalis* by MARUKAWA (1908).

Occurrence. The species is one of the most common surface-living copepod of the Izu region; it is abundant in summer season.

Distribution. The species has a wide distribution in the warm regions of the oceans.

Family EUCALANIDAE

Genus *Eucalanus* DANA, 1848

Eight species belonging to the genus have been recorded from the Japanese waters, namely: *E. attenuatus* (DANA), *E. elongatus* (DANA), *E. crassus* GIESBECHT, *E. mucronatus* GIESBRECHT, *E. pileatus* GIESBRECHT, *E. subcrassus* GIESBRECHT, *E. subtenuis* GIESBRECHT and *E. giesbrechti* MORI; all of them occurred in the present collection. Beside these, *E. bungii californicus* JOHNSON was found from the deep water of Suruga Bay. It has been reported by GIESBRECHT that there are three varieties of *Eucalanus elongatus* DANA: var. *hyalinus*, var. *inermis* and var. *bungii*; of these, *hyalinus* is the Atlantic form. According to Dr. M. W. JOHNSON var. *hyalinus* and var. *inermis* are the tropical or sub-tropical variant and var. *bungii* is the boreal variant of the Pacific. Of these three varieties, var. *bungii* has been obtained abundantly in the North-East

Pacific; var. *inermis* and var. *hyalinus* in small number off the coast of California. He, after studying the developmental stages and the geographical distribution of these varieties, raised var. *bungii* and var. *inermis* to specific rank. Moreover, he established a new subspecies of var. *bungii* which is the southern form of var. *bungii*, and named *E. bungii californicus*. Of these variants, I have recorded the occurrence of var. *bungii* from the surface water of Sagami Bay in winter season, but the occurrence of var. *bungii californicus* has not been known untill the deep water hauls in Suruga Bay caught it in the collection. Nine species, in all, have been obtained in the present material; they appear to be the warm water inhabitant except *E. bungii bungii* and *E. bungii californicus*.

According to SEWELL, *Eucalanus acus* FARRAN, taken in the south of New Zealand, is synonym of *E. longiceps* MATHEWS which had been collected in the Indian Seas. SEWELL recorded the occurrence of eight species from the Indian Seas, namely, *E. attenuatus*, *E. elongatus*, *E. crassus*, *E. longiceps*, *E. monachs*, *E. mucronatus*, *E. pileatus*, and *E. subcrassus*. A. SCOTT recorded also six species with the exception of *E. attenuatus* and *E. elongatus*. VERVOORT recorded seven species in the Snellius Expedition. He is of opinion that JOHNSON's species of *E. elongatus* has no specific value.

Eucalanus attenuatus (DANA)

(Fig. 4, *a–d*)

Eucalanus attenuatus GIESBRECHT, 1892, p. 131, t. 3, 11, 35; ESTERLY, 1905, p. 133; G. O. SARS, 1925, p. 78; FARRAN, 1929, p. 218; SEWELL, 1929, p. 47; WILSON, 1932, p. 32; TANAKA, 1935, p. 145, pl. 11; MORI, 1937, p. 22, pl. 8; FARRAN, 1936, p. 78; VERVOORT, 1947, p. 95.

Length. Female, 4.32–4.43 mm, Male, 3.24–3.42 mm.

Occurrence. Very common in the surface and deep layers.

Distribution. The species is widely distributed in the Pacific, Atlantic and Indian Oceans.

Remarks. Among the specimens of *E. attenuatus* DANA taken in winter season from Sagami Bay, there occurred often large individuals which differ slightly from the typical *E. attenuatus* in the proportional lengths of the joints of the male 5th pair of legs (fig. 4 b). The specimen measured 4.76 mm in the female, and 4.40–4.54 mm in the male.

There is another form of *E. attenuatus* which differs either of them above stated in the following: the genital segment of the female is wider than long (fig. 4 c); the thoracic segments and the 1st to 2nd abdominal segments are covered with fine short hairs; this specimen measured 5.72–6.19 mm in the female, and 4.50–4.67 mm in the male of 5th copepodid stage (fig. 4 d, e).

These specimens were taken mixed with the typical form of *E. attenuatus* in winter 1930, from the surface water of Sagami Bay; they may perhaps be the nor-

thern varieties of *E. attenuatus* (DANA).

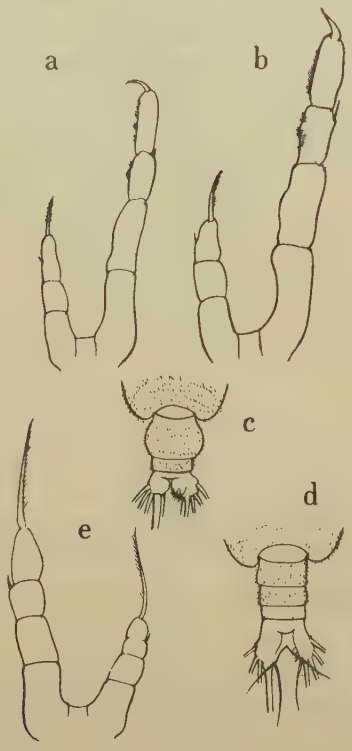


Fig. 4. *Eucalanus attenuatus* (DANA). *a*, Male: 5th pair of legs of the type specimen; *b*, 5th pair of legs of large specimen, measuring 4.40–4.54 mm; *c*, female: abdomen of large specimen; *d*, male: juv. larger specimen, abdomen, dorsal aspect; *e*, 5th pair of legs.

Eucalanus elongatus (DANA)

Eucalanus elongatus GIESBRECHT, 1892, p. 131, t. 11, 35; G. O. SARS, 1925, p. 20; FARRAN, 1929, p. 218; SEWELL, 1929, p. 48; WILSON, 1932, p. 31; TANAKA, 1935, p. 143, pl. 1; FARRAN, 1936, p. 78; MORI, 1937, p. 21, pl. 7; VERVOORT, 1947, p. 84.

Length. Female, 5.62–5.76 mm. The specimen has laterally produced thoracic margins, and is slightly spinulated on the dorsal surface. The 1st leg has an internal setae on the 2nd basal joint.

Occurrence. The species has been obtained both from the surface and deep waters in small quantity.

Distribution. The species has wide distribution in the Pacific, Atlantic and Indian Oceans.

Eucalanus bungii var. *bungii* (JOHNSON)

Eucalanus elongatus var. *bungii* GIESBRECHT, 1892, p. 149; SATO, 1913, p. 2; *Eucalanus elongatus* var. *bungii* TANAKA, 1935, p. 143, pl. 1; *Eucalanus giesbrechti* MORI, 1937, p. 22, pl. 7; *Eucalanus bungii bungii* JOHNSON, 1938, p. 167, figs. 4–10, 18, 20, 23, 25; *Eucalanus elongatus* VERVOORT, 1947, p. 84.

Length. Female, 6.30 mm. Male, copepodid stage V, 5.50 mm.

Remarks. This species is easily distinguished from *E. elongatus* by the rounded corners of the 5th thoracic segment, and by the presence of three setae on the 2nd basal joint of the mandible. MORI raised the species to the rank of species under the name *E. giesbrechti*. JOHNSON revised it as *E. bungii bungii*, a subspecies of *E. bungii*. VERVOORT advices to distinguish two forms in *E. elongatus*: the Pacific form with smoothly rounded lateral thoracic margins, symmetrical 1st antennae and without any indication of spinules on the dorsal surface and, the Atlantic form with produced thoracic margins, asymmetrical 1st antenna and spinulated dorsal surface. But in my opinion it is better to distinguish the former with rounded thoracic margins from the latter with produced thoracic margins under the name *E. bungii*. The present specimen, *E. bungii* var. *bungii*, is the northern variety of *bungii*.

Eucalanus bungii var. *californicus* (JOHNSON)

(Fig. 5, *a–d*)

Eucalanus elongatus ESTERLY, 1905, p. 131.
Eucalanus bungii californicus JOHNSON, 1938, p. 169, fig. 22.

Remarks. This species agrees with *E. elongatus* var. *bungii* GIESBRECHT except that the 2nd basal of the mandible is furnished with a single seta. According to JOHNSON, *E. bungii* var. *bungii* is a northern variety of *E. elongatus*, and *E. bungii californicus* is a southern variety of *E. bungii* which is common in the California coast. According to JOHNSON, *E. elongatus* ESTERLY is identical with the present species. JOHNSON elevated this species to the rank of subspecies, but it seems reasonable to keep the subspecies as a variety.

Length. Female, 6.18 mm, cephalothorax, 5.62 mm, abdomen, 0.56 mm. The cephalothorax elongate oval, produced narrowly anteriorly. The abdomen is contained 10-times in the length of the cephalothorax; the abdomen 3-segmented, the segments and the furca in the proportions 47 : 18 : 12 : 23 = 100; the furcal rami slightly asymmetrical.

The 1st antenna exceeds the end of the furca by terminal two or three joints. The 2nd antenna has 8-jointed endopodite; the 1st and 2nd basal joints of the exopodite are of equal lengths. The mandible has a slender 2nd basal joint which is furnished with one seta on the proximal inner margin; the exopodite is situated about the middle of the 2nd basal joint. The maxillae and maxillipede are as those of *E. elongatus* (DANA).

The 3rd joint of the exopodite of 1st leg has two outer marginal spines. The 2nd to 4th legs as those of *E. elongatus*.

Occurrence. The species has been collected, only in small numbers, from the deep water of Suruga Bay, but not a single specimen from Sagami Bay.

Distribution. The specimen has been recorded only from the California coast.

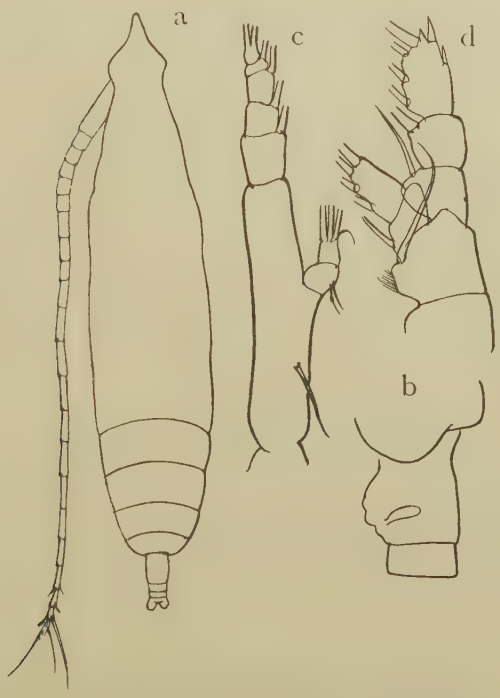


Fig. 5. *Eucalanus bungii* var. *californicus* (JOHNSON). *a*, Female, dorsal aspect; *b*, last thoracic segment and genital segment, lateral aspect; *c*, mandible; *d*, 1st leg.

Eucalanus crassus GIESBRECHT

Eucalanus crassus GIESBRECHT, 1892, p. 132, t. 11, 35; ESTERLY, 1905, p. 134; A. SCOTT, 1909, p. 19; WITH, 1915, p. 53; SARS, 1925, p. 22; FARRAN, 1929, p. 220; SEWELL, 1929, p. 50; FARRAN, 1936, p. 78; TANAKA, 1935, p. 145, pl. 5; MORI, 1937, p. 23, pl. 9; VERVOORT, 1947, p. 112; *E. oculanus* MARUKAWA, 1921, p. 7.

Length. Female, 3.17–3.73 mm. Male, 3.13–3.49 mm.

Occurrence. Common in the surface water.

Distribution. The species is widely distributed in the warm regions of the oceans.

Eucalanus mucronatus GIESBRECHT

Eucalanus mucronatus GIESBRECHT, 1892, p. 132, t. 11, 35; A. SCOTT, 1909, p. 20; G. O. SARS, 1925, p. 21; FARRAN, 1925, p. 218; TANAKA, 1935, p. 147, pl. 3; FARRAN, 1936, p. 78; MORI, 1937, p. 25, pl. 8; VERVOORT, 1947, p. 104.

Length. Female, 3.13–3.49 mm.

Occurrence. Rather rare; the male specimens were all immature.

Distribution. The species has a wide distribution in the warm regions of the oceans, but according to SEWELL the species is not common in the Indian Ocean.

Eucalanus pileatus GIESBRECHT

Eucalanus pileatus GIESBRECHT, 1892, p. 132, t. 11, 35; A. SCOTT, 1909, p. 21; WOLFENDEN, 1911, p. 204; SEWELL, 1929, p. 51; TANAKA, 1935, p. 148, pl. 4.

Length. Female, 2.11–2.41 mm. Male, 2.16 mm.

Occurrence. Rather rare.

Distribution. The species has been recorded from the Pacific, Atlantic, Malay Archipelago, Maldive Archipelago and Indian Ocean.

Eucalanus subcrassus GIESBRECHT

Eucalanus subcrassus GIESBRECHT, 1892, p. 132, pl. t. 11, 35; A. SCOTT, 1909, p. 21; FARRAN, 1929, p. 219; SEWELL, 1929, p. 51; TANAKA, 1935, p. 51, pl. 4; FARRAN, 1936, p. 75; MORI, 1937, p. 24, pl. 9; VERVOORT, 1947, p. 108.

Length. Female, 2.77–2.82 mm. Male, 2.52 mm.

Occurrence. Rare.

Distribution. The species is widely distributed in the tropical and subtropical regions, and has been recorded from the Atlantic, Indian Oceans, Malay Archipelago and Great Barrier Reef.

Eucalanus subtenuis GIESBRECHT

Eucalanus subtenuis GIESBRECHT, 1892, p. 132, t. 11, 35; ESTERLY, 1905, p. 135; MARUKAWA, 1908, p. 6, pl. 1, 2; A. SCOTT, 1909, p. 21; G. O. SARS, 1925, p. 21; FARRAN, 1929, p. 218; TANAKA, p. 147, pl. 3; MORI, 1937, p. 25; VERVOORT, 1947, p. 106.

Length. Female, 3.22–2.40 mm. Male, 3.06–2.63 mm.

Occurrence. One of the most common species.

Distribution. The species has been recorded from the Pacific, Atlantic, Mediterranean Sea, and Malay Archipelago; but the occurrence of the species has not been recorded from Indian Ocean.

Genus *Rhincalanus*, DANA, 1848

Three species belonging to this genus have been recorded from the Japanese waters: *Rhincalanus cornutus* DANA, *R. nasutus* GIESBRECHT and *R. gigas* BRADY. The last species has been described by MARUKAWA (1908) from the immature specimen taken from the surface waters off the coast of the Prov. Izu. His figures are, as pointed out by SCHMAUSS, uncertain. He described that the specimen is a female, measuring 7.8–9.0 mm in total length; but the figure (Fig. 59) given as the 5th pair of legs,

indicates that the specimen is not female at all, but an immature male; the 2nd to 4th thoracic segments have each a pair of dorsal and lateral spines and dorsal spines on the 1st abdominal segment. The immature male specimen of *R. gigas* has the lateral spines on the 3rd and 4th thoracic segment, and dorsal spines only on the 4th thoracic and on the 1st abdominal segment. MARUKAWA's figure of the 5th pair of legs agrees those of *R. gigas* or *R. nasutus*, in having a long endopodite on the left leg. His specimen differs from *R. gigas* in the spinulation of the thoracic segments which is the sufficient reason for identifying the both species. His specimen measures about 3.2–5.4 mm, calculating from the magnification of the microscope used, and from the figures of the entire body of the other species on the same plate. Again considering the geographical distribution of *R. gigas*, it is confined to the Antarctic water south of Lat. 37° S; the occurrence of the species in the upper layer of the northern temperate region seems very doubtful. SCHMAUSS identified MARUKAWA's specimen as *R. cornutus* forma *typica*; perhaps for the reasons that the specimen has both lateral and dorsal spines on the 2nd thoracic segment; but the shape of the forehead quite differs from that of *R. cornutus* in MARUKAWA's specimen. *R. nasutus* in Japanese waters has both lateral and dorsal spine on the 2nd thoracic segment. From the reasons above stated, MARUKAWA's specimen is the immature male of *R. nasutus* which is common in Japanese waters.

Rhincalanus nasutus GIESBRECHT

Rhincalanus nasutus GIESBRECHT, 1892, p. 132, t. 3, 9, 12, 35; G. O. SARS, 1903, p. 18; ESTERLY, 1905, p. 136; *R. gigas* MARUKAWA, 1908, p. 3, pl. 2, figs. 49–59; A SCOTT, 1909, p. 24; SCHMAUSS, 1927, p. 368; FARRAN, 1929, p. 220; SEWELL, 1929, p. 58; WILSON, 1932, p. 34; TANAKA, 1935, p. 151; FARRAN, 1936, p. 79; MORI, 1937, p. 26, pl. 10; VERVOORT, 1949, p. 122.

Length. Female, 3.60–4.50 mm. Male, 3.74–3.81 mm.

Remarks. The specimen from the Japanese waters has both lateral and dorsal spines on the 2nd thoracic segment.

Occurrence. Common. It is rather abundant in the deep layers.

Distribution. The species has a wide distribution in the oceans.

Rhincalanus cornutus DANA

Rhincalanus cornutus GIESBRECHT, 1892, p. 153, t. 12; A. SCOTT, 1909, p. 32; G. O. SARS, 1925, p. 22; SCHMAUSS, 1927, p. 359; FARRAN, 1929, p. 220; SEWELL, 1929, p. 58; WILSON, 1934, p. 35; TANAKA, 1935, p. 151; FARRAN, 1936, p. 79; MORI, 1937, p. 27, pl. 10; VERVOORT, 1947, p. 116.

Length. Female, 3.24–3.63 mm.

Remarks. The specimen agrees well with description and figures of *R. cornutus* f. *typica* given by SCHMAUSS. The male specimens were all immature in the 5th copepodid stage.

Occurrence. Common in the surface layer.

Distribution. The species has a wide distribution in the oceans.

Genus *Mecynocera* THOMPSON, 1888

Mecynocera clausi THOMPSON

Mecynocera clausi GIESBRECHT, 1892, p. 160, t. 5, 11, 35; THOMPSON, 1894, p. 80; ESTERLY, 1905, p. 137; SARS, 1925, p. 23; FARRAN, 1929, p. 221; SEWELL, 1929, p. 60; WILSON, 1932, p. 36; TANAKA, 1935, p. 152, p. 4; FARRAN, 1936, p. 79; MORI, 1937, p. 28, pl. 11, 12.

Female. Length, 0.94–0.99 mm.

Occurrence. Common species in the surface layer.

Remarks. The adult male specimen has not been met with in Japanese waters. It has been recorded from the Gulf of Guinea. The male 5th legs have been described as follows: "The 5th pair are one-branched, alike on both sides and in both sexes; basal portion two-jointed; not much stouter than the terminal portion which is three-jointed. There is, so far as could be observed, no terminal spine."

Distribution. The species is of a wide distribution, and has been recorded from warm waters of the oceans.

INVERTEBRATE FAUNA OF THE INTERTIDAL ZONE OF THE TOKARA ISLANDS

XII. FORAMINIFERA[1)2)]

YUKIO KUWANO
Research Institute for Natural Resources, Tokyo

With Plates XXVIII–XXX and 1 Text-figure

The foraminiferal materials here discussed are submitted to the writer by Dr. T. TOKIOKA of the Seto Marine Biological Laboratory, who visited the Tokara Islands, during the period from May 26 to June 12 of 1953, for the biological survey.

As the purpose of this survey and the outline of the results obtained were already described by Dr. T. TOKIOKA (this journal, III (2), 1953), the writer wishes to give the results of identification of the submitted materials and brief notes on the species distinguished in the following.

The materials treated herein are deposited in the collection of the Seto Marine Biological Laboratory.

1. On the Occurrence of the Samples

The submitted materials are divided into two groups according to the mode of occurrence, namely, the reef surface samples and the beach sand sample. The former are composed of the tests attached on the surface of the reef and of the organisms living there, and the latter of the dead tests contained in the beach sand.

The intertidal zone where these samples were collected is clearly divided into four zones characterized by distinct colouration, according to T. TOKIOKA. The zones are as in the following table (from beach to reef edge).

	Takarazima	Nakanosima	
Beach ↑	Greyish Zone	Rocky Zone	
	Yellowish Zone		Yellowish Zone
	Purplish Zone	Purplish Zone	
↓ Reef edge	Brownish Zone	Brownish Zone	

1) Scientific Survey of the Tokara Islands, Report No. 23.
2) Contributions from the Research Institute for Natural Resources, No. 771.

a) *The reef surface samples.* These were gathered from the lower half of the intertidal zone, i.e. the part lower than the purplish zone, of Takarazima and Nakanosima.

Among the higher and larger organisms dwelling on the reef surface, two species of foraminifer, which attains to large size, are remarkable. They are described by T. TOKIOKA as *Baculogypsina sphaerulata* (PARKER et JONES) and *Orbitolites complanata* LAMARCK.[1] The former is abundantly found on the surface of the reefs and organisms on the reef in Nakanosima (lower than the lower half of the purplish zone). The latter is commonly discovered along the reef edge in Takarazima (brownish zone).

Except these two there is no remarkable, or abundantly occurring foraminifer, that may be distinguished to the naked eye.

b) *The beach sand sample.* This was collected in Takarazima on the narrow sand beach, which is a part of the yellowish zone, where raised coral reefs eroded to form the deeply excavated cavities, and on the bottom of these cavities the white calcareous sand is deposited to form narrow sand beach or pockets.

This sand is very coarse-grained, and the fraction coarser than 0.59 mm in diameter attains to over 90% weight of the whole sample. The grains are from subangular to angular, and are the fragments of calcareous skeletons and shells of such organisms as corals, molluscs and foraminifers. In general, the deposition of coarse-grained calcareous sand seems to be a general feature of the tropical and subtropical beach, the angulosity of grains varies from place to place, being probably affected by minor topographic elements of the beach. The largeness of angulosity of this sample is probably due to the irregularly eroded and uneven surface of the reef in Takarazima. Therefore, the state of preservation of the foraminiferal tests contained in this sample is fairly well, compared with that recovered from the sand on the flat and open beach.

2. Results

The list of the species distinguished is as follows:

	The reef surface sample		The beach sand sample
	Takarazima	Nakanosima	Takarazima
Textularia sp.	—	—	1
Gaudryina (*Siphogaudryina*) *siphonifera* (BRADY)	—	—	3
Elphidium "crispum" (LINNÉ)	2	—	—
Heterostegina depressa D'ORBIGNY	—	7	29 (6.1%)
Heterostegina suborbicularis (LAMARCK)	1	—	1
Heterostegina cf. *suborbicularis* (LAMARCK)	—	1	1
Peneroplis pertusus (FORSKÅL)	—	—	2
Amphisorus hemprichii EHRENBERG	—	—	3

1) *Orbitolites complanata* LAMARCK of TOKIOKA=*Marginopora vertebralis* BLAINVILLE.

Marginopora vertebralis BLAINVILLE	42(+4*)	4	52* (11.0%)
Borelis sp.	—	—	1
Rotalia beccarii (LINNÉ) var.	—	—	3
Eponides (*Poroeponides*) *concameratus* (MONTAGU) var.	—	—	9
Amphistegina radiata (FICHTEL et MOLL)	35	16	53 } (24.3%)
Amphistegina sp.**	6	9	62 }
Calcarina defrancii D'ORBIGNY	4	47	67 (14.1%)
Calcarina cf. *hispida* BRADY	—	1	—
Baculogypsina sphaerulata (PARKER et JONES)	61	ca. 800	133 (27.9%)
Cymbaloporetta bradyi (CUSHMAN)	—	—	2
Gypsina? sp.	—	—	5
Planorbulinella larvata (PARKER et JONES)	—	—	7
Homotrema rubrum (LAMARCK)	—	—	25*
Gen. et sp. indet.	—	—	16
			Total 474 indiv.

* Fragments.
** Probably could be referred to *A. radiata*.

a) *The reef surface samples.* As the collection of these samples are not so precisely designed, the results listed above do not necessarily represent the specific composition of the living assemblages on the reefs of these islands. However, they are sufficient for us to conclude on the general character of this assemblages of these islands. The predominant species, *Baculogypsina sphaerulata* (PARKER et JONES) and the species associated with it, i.e. *Amphistegina radiata, Marginopora vertebralis, Calcarina defrancii*, are the tropical and subtropical species, commonly found in the shallow waters of the Indo-Pacific Region.

b) *The beach sand sample.* The death assemblage contained in this sample, is characterized as *Baculogysina sphaerulata—Amphistegina radiata—Calcarina defrancii* Assemblage. The specific composition is quite similar to that of the reef surface sample in Nakanoshima, except that *Baculogypsina sphaerulata* is so far abundant than the other species in the latter, that we might call it as *Baculogypsina sphaerulata* Assemblage. However, whether the specific composition of these two assemblages represents the same fauna or not, remains as a question, until more detailed investigations will touch this point.

3. Comparison with the Data Hitherto Known

The foraminiferal assemblages of intertidal zone in the Tokara Islands are evidently of tropical and subtropical nature, as already stated. Therefore, our attentions should be called to the comparisons with the intertidal assemblages from the more northern waters.

On the Pacific side of Japan, most of the tropical and subtropical species found from the Tokara Islands occur fairly rich in Kannoura, Sikoku (ASANO, 1937). There the beach sand contains such tropical and subtropical species as *Amphistegina radiata*, *Calcarina spengleri* (abundant), *Marginopora vertebralis*, *Rotalia calcar*, *Calcarina mayori*, *Miniacina miniacea* (common), and *Heterostegina depressa* (rare). However, with these species are found many miliolid species, which are common in the warm waters around Japan. These miliolids are the principal constituents of the shallow water assemblages of middle Honsyû together with many species belonging to the other genera. For example, *Elphidium "crispum," Cibicides refulgens*, and several species of the genus *Textularia*.

From Sikoku to northward, the tropical and subtropical elements suddenly decrease in number of species and individuals. In the Ago Bay, no tropical and subtropical species except *Amphistegina radiata* and *Marginopora vertebralis* is found, and all the other species occurring there are the elements of warm water assemblages (MORISHIMA, 1948, 1950). Here *Amphistegina radiata* is one of the principal constituents of *Amphistgina—Elphidium crispum* Assemblage, and its frequency of occurrence attains to 20–30%. But *Marginopora vertebralis* is found in lower frequency (less than 5%). In the bay mouth area of the Tokyo Bay, only few individuals of *Amphistegina radiata* are found and the occurrence of *Marginopora* is not hitherto known (KUWANO, MS). The writer supposes that the northern limit of *Amphistegina radiata* is to be lined just north off the Bôsô Peninsula.

It is hitherto known that the beach sand assemblge from Hatizyôzima contains several tropical and subtropical species as follows: *Amphistegina radiata, Amphisorus hemprichii, Heterostegina depressa, Peneroplis pertusus, Planorbulinella larvata*, and *Gaudryina* (*Siphogaudryina*) *siphonifera* (UCHIO, 1952). However, except *Amphistegina radiata*, the frequency of occurrence of these species is lower than that of the representatives of the miliolids, the genera *Textularia, Discorbis*, etc.

On the Japan Sea side of Japan, *Amphistegina radiata* and *Marginopora vertebralis* are found from the Obama Bay (MORISHIMA, 1948, 1950). The distribution pattern of these two species are quite similar as in the Ago Bay. Judging from the previously published data, the distribution area of them does not extend to the more northern waters off Niigata Prefecture (OINOMIKADO and STACH, 1948).

On the basis of these comparisons, it can be safely concluded that any assemblage, which is equivalent to that of the Tokara Islands, is not present in the shallow waters around middle Honsyû and that the tropical and subtropical elements completely disappear off the middle part of Honsyû.

It is evident that the above-mentioned differences between several assemblages are caused by different ecological factors in the areas concerned. However it seems that these differences are more complicated by the presence of the other factors. For example, the examination of the intertidal material collected in Okinoerabuzima reveals somewhat different aspects as to the foraminiferal fauna. This material was recovered

from the surface of a bivalved molluscan shell dwelling in the tide pool on the reef surface in Okinoerabuzima, where the similar climatic factors probably governs, though this island is situated geographically more south than the Tokara Islands. The principal constituents of the Okinoerabu assemblage are the representatives of the genera *Amphistegina*, *Calcarina* (fairly rich in individual numbers), *Discorbis*, *Discopulvinulina*, *Cibicides*, *Entosolenia*, *Buliminella* and *Bolivina* (rich in individual numbers and number of species). And such dominant species in the Tokara Islands as *Baculogypsina sphaerulata* and *Marginopora vertebralis* decrease much in individual numbers. Besides, this assemblage is composed of the foraminiferal tests varying considerably in the size of test, while the reef surface assemblage from the Tokara Islands is chiefly composed of the tests of fairly large size.

The writer considers that the cause of these differences should be left as a problem, until more detailed survey will be carried out in the future. However, the difference of the sampling method (as to the reef surface samples), and the difference of the mechanical sorting of shore sand by waves (as to the beach sand sample) are temporarily suggested.

4. Notes on the Species

Gaudryina (*Siphogaudryina*) *siphonifera* (Brady)

(Pl. XXVIII, Figs. 1–3)

The northern limit of distribution in Japan: Tokyo Bay, bay mouth area (Kuwano, MS). Recorded from off the Ryûkyû Islands (Hanzawa, 1928); and Hatizyôzima, beach sand, less than 0.1% (Uchio, 1952). TK. Nos. 502–503.

Heterostegina depressa d'Orbigny

(Pl. XXVIII, Figs. 4–7)

The northern limit of distribution in Japan: Kannoura, Sikoku, beach sand (Asano, 1937). Recorded from off the Ryûkyû Islands (Hanzawa, 1928); and Hatizyôzima, beach sand, 0.1–1.0% (Uchio, 1952). TK. Nos. 505–508.

Heterostegina suborbicularis (Lamarck)

(Pl. XXVIII, Figs. 8, 9)

Newly recorded from the Japanese waters. TK. Nos. 509, 509a.

Peneroplis pertusus (Forskål)

The northern limit of distribution in Japan: Koaziro, Miura Peninsula, beach sand,

rare (*Peneroplis* sp.) (HIGUCHI, 1954). Recorded from the coast of Ryûkyû (YABE and HANZAWA, 1925). TK. No. 511.

Amphisorus hemprichii EHRENBERG

The northern limit of distribution in Japan: Hatizyôzima, beach sand, 1–5% (UCHIO, 1952). Recorded from the coast of Ryûkyû (YABE and HANZAWA, 1925); and off Ryûkyû (HANZAWA, 1928). TK. 512.

Marginopora vertebralis BLAINVILLE

(Pl. XXVIII, Figs. 10-17)

The northern limit of distribution in Japan: Ago Bay, the middle part, less than 5% (MORISHIMA, 1950). Recorded from Kannora, Sikoku, beach sand (ASANO 1937). TK. Nos. 513–519, 530.

Eponides (*Poroeponides*) *concameratus* (MONTAGU) var.

(Pl. XXIX, Figs. 2, 3)

TK. Nos. 522–523.

Amphistegina radiata (FICHTEL et MOLL)

(Pl. XXIX, Figs. 4–9)

In the adult individuals, the form of test widely varies from biconvex to planoconvex, and the forms of sutures from deeply meandered to simple. The convexity of of the test increases as the test grows.

The northern limit of distribution in Japan: Tokyo Bay, bay mouth area (KUWANO, MS). Recorded from the coast of the Ryûkyû Islands (YABE and HANZAWA, 1925); off Ryûkyû (HANZAWA, 1928); Tanegasima (HANZAWA, 1935); Kannoura, Sikoku (ASANO, 1937); Tanabe Bay (MORISHIMA, 1950); Ago Bay, bay mouth area, 20–30% (MORISHIMA, 1950); Sagami Bay (ASANO, 1937); Hatizyôzima, beach sand, 15–20% (UCHIO, 1952); Obama Bay, bay mouth area, 10% (MORISHIMA, 1948); Wakasa Bay (ASANO, 1937). TK. Nos. 524–529.

Calcarina defrancii D'ORBIGNY

(Pl. XXIX, Figs. 10–14)

Newly recorded from the Japanese waters. TK. Nos. 534-541.

Calcarina cf. *hispida* BRADY

(Pl. XXX, Figs. 1–3)

Recorded from off the Ryûkyû Islands (*Calcarina hispida* BRADY) (HANZAWA,

1928). TK. No. 542.

Baculogypsina sphaerulata (PARKER et JONES)

(Pl. XXX, Figs. 4–9; Text-fig. 1)

Among a number of individuals of this species from Nakanosima (the reef surface sample), a few specimens with remarkably different surface ornamentation are found. The outer wall of the test like bubbles and no papillae is present on the surface of it. Some of the radial spines do not extend in the plane of coiling (along the equatorial plane of the test), hence the normal, radial arrangement of the spines are irregularly

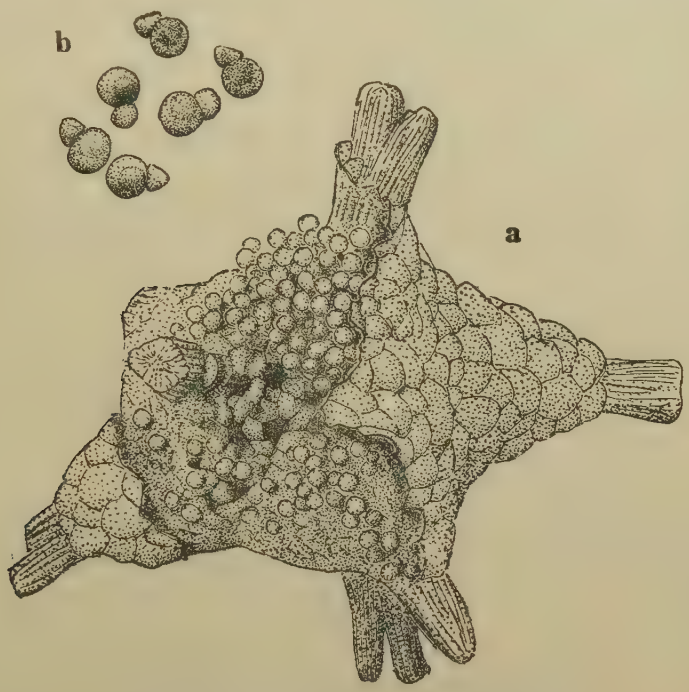


Fig. 1. *Baculogypsina sphaerulata* (PARKER et JONES).
a, A parental test containing the young organisms, the outermost wall partially broken. Max. diam. (including spines), 2.7 mm. Nakanosima, reef surface. *b*, Two chambered young organisms. Magnified about 80 times.

modified. The spines of these individuals are irregularly doubled, or sometimes represented by groups of small processes, 4–6 in number (Pl. XXX, Fig. 9). Among them one individual which contains a number of two-chambered young just inside the outermost wall is found (Text-fig. 1a, b). These young individuals are found in the chamber formed between the outermost wall and the inner wall. On the surface of the inner wall, several papillae are observed. They are arranged a little coarser than

those of the normal individuals and are larger in size. Considering from the fact that among a number of individuals with normal ornamentation from Nakanosima and Takarazima, individuals with somewhat coarser arranged papillae are rather commonly found (Pl. XXX, Fig. 7), the above-mentioned individual with young organisms represents the representative of the same species as a number of individuals with normal ornamentation. The presence of the young individuals in the parental test suggests that this individual is an agamont, and collected just after the schizogony, and that this species has the same reproductive process as in *Iridia serialis*, which also forms young organisms inside the parental test, in so far as the agamont generation is concerned.

The northern limit of distribution in Japan: Tanegasima (HANZAWA, 1935). TK. Nos. 543–552.

Cymbaloporetta bradyi (CUSHMAN)

(Pl. XXX, Figs. 10, 11)

The northern limit of distribution in Japan: off Kusiro, Hokkaido (TAKAYANAGI, 1953). Recorded from Zusi and Koaziro, Miura Peninsula, beach sand (HIGUCHI, 1954); Siogama Bay (ASANO, 1937); off Isizi, Niigata Prefecture (OINOMIKADO and STACH, 1948). TK. Nos. 553–554.

Planorbulinella larvata (PARKER et JONES)

(Pl. XXX, Figs. 12, 13)

The northern limit of distribution in Japan; Hatizyôzima, beach sand, less than 0.1% (UCHIO, 1952). Recorded from off the Ryukyu Islands (HANZAWA, 1928). TK. Nos. 556–557.

Homotrema rubrum (LAMARCK)

TK. No. 558.

Acknowledgment

The writer expresses his cordial thanks to Dr. T. TOKIOKA, who kindly give the opportunity to examine the material collected by him during the Tokara Scientific Expedition.

REFERENCES

Asano, K. 1937. A comparion of the Recent Foraminifera from Tosa Bay and the Pliocene Foraminifera from Aki-gun, Province Tosa. Journ. Geol. Soc. Japan, **44** (520), pp. 36–55.

———— 1937. Foraminifera from Siogama Bay, Miyagi Prefecture, Japan. Saitô Hô-on Kai Museum, Res. Bull. No. 13, pp. 109–119.

Cushman, J. A. 1910–1916. A Monograph of the Foraminifera of the North Pacific Ocean. U. S. Nat. Mus., Bull. 71, 596 pp.

Hanzawa, S. 1928. Preliminary report on marine deposits from the southwestern North Pacific Ocean. Rec. Oceanogr. Wks. in Japan, **1** (2), pp. 59–77.

———— 1935. Topography and Geology of the Riukiu Islands. Sci. Rep. Tôhoku Imp. Univ., Ser. 2 (Geol.), **17**, pp. 1–61.

Higuchi, Y. 1954. Fossil Foraminifera from the Miyata Formation, Miura Peninsula, Kanagawa Prefecture. Journ. Geol. Soc. Japan, **60** (703), pp. 138–144.

Morishima, M. 1948. On the accumulations of foraminiferal tests in Obama and Maizuru Bays. Physiol. & Ecol., **2** (3/4), pp. 42–58. (In Japanese with English résumé)

———— 1950. Accumulation of foraminiferal tests in Ago Bay (Studies on the pearl fishery ground of the Ago Bay, IV). Cont. to Physiol. & Ecol., Kyoto Univ., No. 72, pp. 62–66. (In Japanese)

Oinomikado, T. & Stach, L. W. 1948. Recent shallow water foraminiferal assemblages from Niigata Prefecture, Japan. Rep. Committ. Treat. Mar. Ecol. Paleoecol., No. 8, 1947–1948. National Research Council, Washington, D. C., pp. 104–110.

Tokioka, T. 1953. Invertebrate fauna of the intertidal zone of the Tokara Islands. I. Introductory notes, with the outline of the shore and the fauna. Publ. Seto Mar. Biol. Lab., **3** (2), pp. 123–137.

Uchio, T. 1952. Foraminiferal assemblage from the Hachijo Island, Tokyo Prefecture, with description of some new genera and species. Jap. Journ. Geol. Geogr., **22**, pp. 145–159.

Yabe, H. & Hanzawa, S. 1925. Globigerina ooze from the sea lying south of Okinawa-jima (Riukiu Islands). Jap. Journ. Geol. Geogr., **4** (1/2), pp. 47–54.

EXPLANATION OF PLATES XXVIII–XXX

Plate XXVIII

Figs. 1–3. *Gaudryina* (*Siphogaudryina*) *siphonifera* (Brady).
Takarazima, beach sand. Length, 1.3 mm.

Figs. 4–7. *Heterostegina depressa* d'Orbigny.
Nakanoshima, reef surface.
4, 5···Max. diam., 1.9 mm.
6, 7···Max. diam., 1.0 mm.

Figs. 8, 9. *Heterostegina suborbicularis* (Lamarck).
Takarazima, beach sand. Max. diam., 2.0 mm.

Figs. 10–17. *Marginopora vertebralis* Blainville.
Takarazima, reef surface. (11–13, inner structure; 14–17, aperture)
10···A test of small size, diam., 4.1 mm.
11, 12···A test of fairly large size, diam., 9.0 mm.
11—Peripheral part.
12—Near the center of the test.
13···A test of small size, diam., 4.0 mm, thickness, 0.2 mm.

14···A test of large size, diam., 10.0 mm, thickness, 0.7 mm.

15···A test of small size, diam., 3.0 mm, thickness, 0.3 mm.

16···The same test as Fig. 10, thickness, 0.3 mm.

17···A test of very small size.

(1, 4, 6, 8, 10–side view; 2–apertural v.; 3–view from the apical end; 5, 7, 9, 14, 15, 16, 17–peripheral v.; 11, 12, 13–section)

PLATE XXIX

Fig. 1. *Borelis* sp. Width, 0.7 mm. Takarazima, beach sand.

Figs. 2, 3. *Eponides* (*Poroeponides*) *concameratus* (MONTAGU) var.
Takarazima, beach sand. Max. diam., 1.2 mm.

Figs. 4–9. *Amphistegina radiata* (FICHTEL et MOLL)

4, 5, 6···A well-developed, biconvex test with deeply meandered sutures. Takarazima, reef surface. Max. diam., 1.6 mm.

7, 8···A test of small size. Thin lenticular form with simple ornamentation. Nakanosima, reef surface. Max. diam., 0.9 mm.

9···A test of small size, with a lip-like projection along the aperture. Takarazima, reef surface. Height of the apertural face, 0.2 mm.

Figs. 10–14. *Calcarina defrancii* D'ORBIGNY
Nakanosima, reef surface.

10, 11, 12···Max. diam. (including spines), 1.7 mm.

13···A test of small size, max. diam., 1.1 mm.

14···Showing the arrangement of the chambers and spines. Max. diam., 1.5 mm.

(1, 9–apertural view; 2, 4, 7, 11, 14–dorsal v.; 3, 5, 8, 10–ventral v.; 6, 12, 13–peripheral v.)

PLATE XXX

Figs. 1–3. *Calcarina* cf. *hispida* BRADY Nakanosima, reef surface.
Max. diam., 1.8 mm.

Figs. 4–9. *Baculogypsina sphaerulata* (PARKER et JONES)

4, 5···Nakanosima, reef surface. Max. diam., 2.2 mm.

6···Ornamentation coarser than the normal state. Takarazima, reef surface. Magnification same as Figs. 4, 7 and 8.

7···Ornamentation shown by breaking the outermost wall of the test, in which the schizogonical processes are prepared. Nakanosima, reef surface.

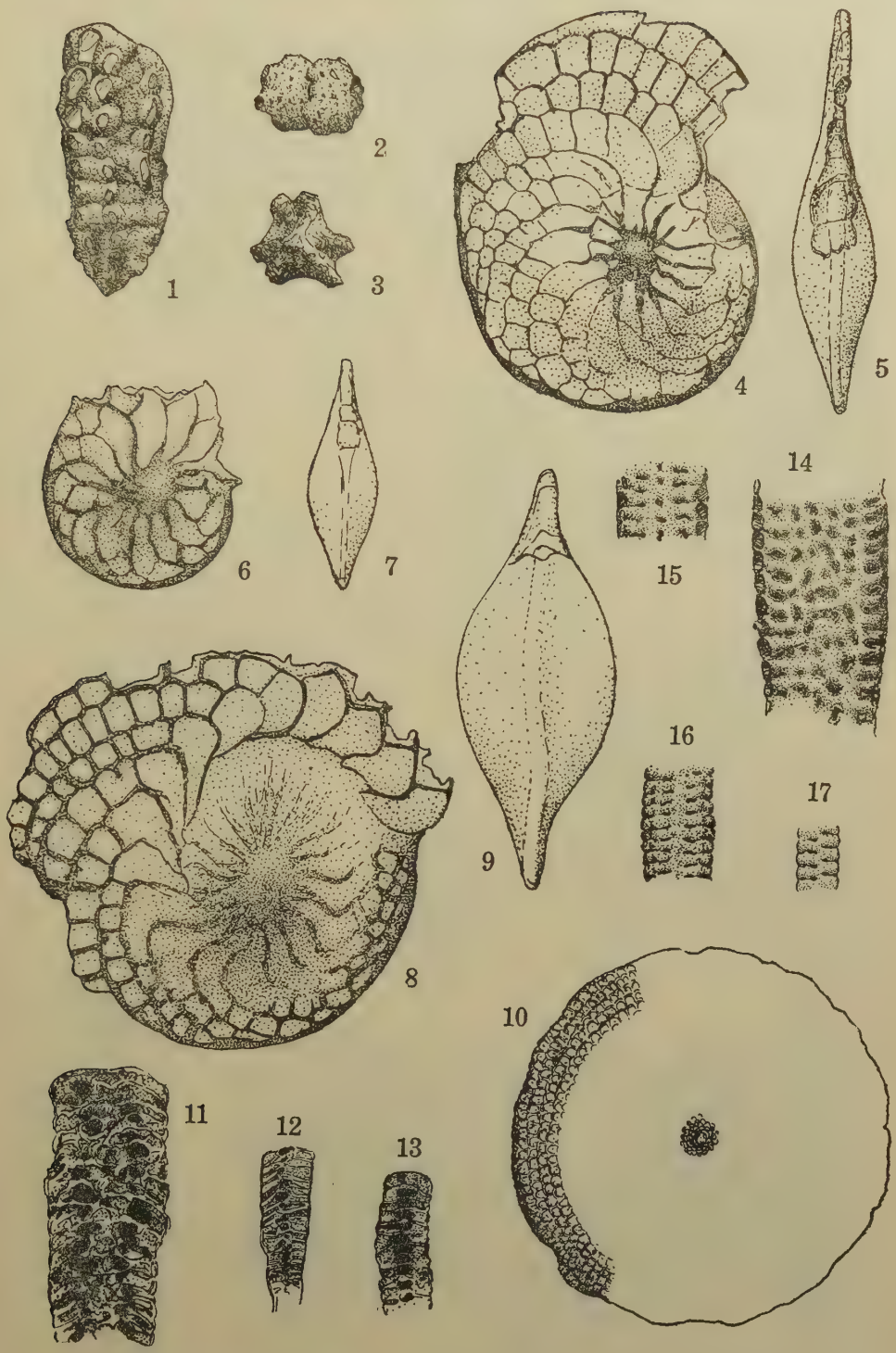
8···Bubble-like surface ornamentation without papillae. Nakanosima reef surface.

9···Double and irregularly divided spines on the test, in which the schizogonical processes are probably prepared. Nakanosima, reef surface. Magnified about about 29 times.

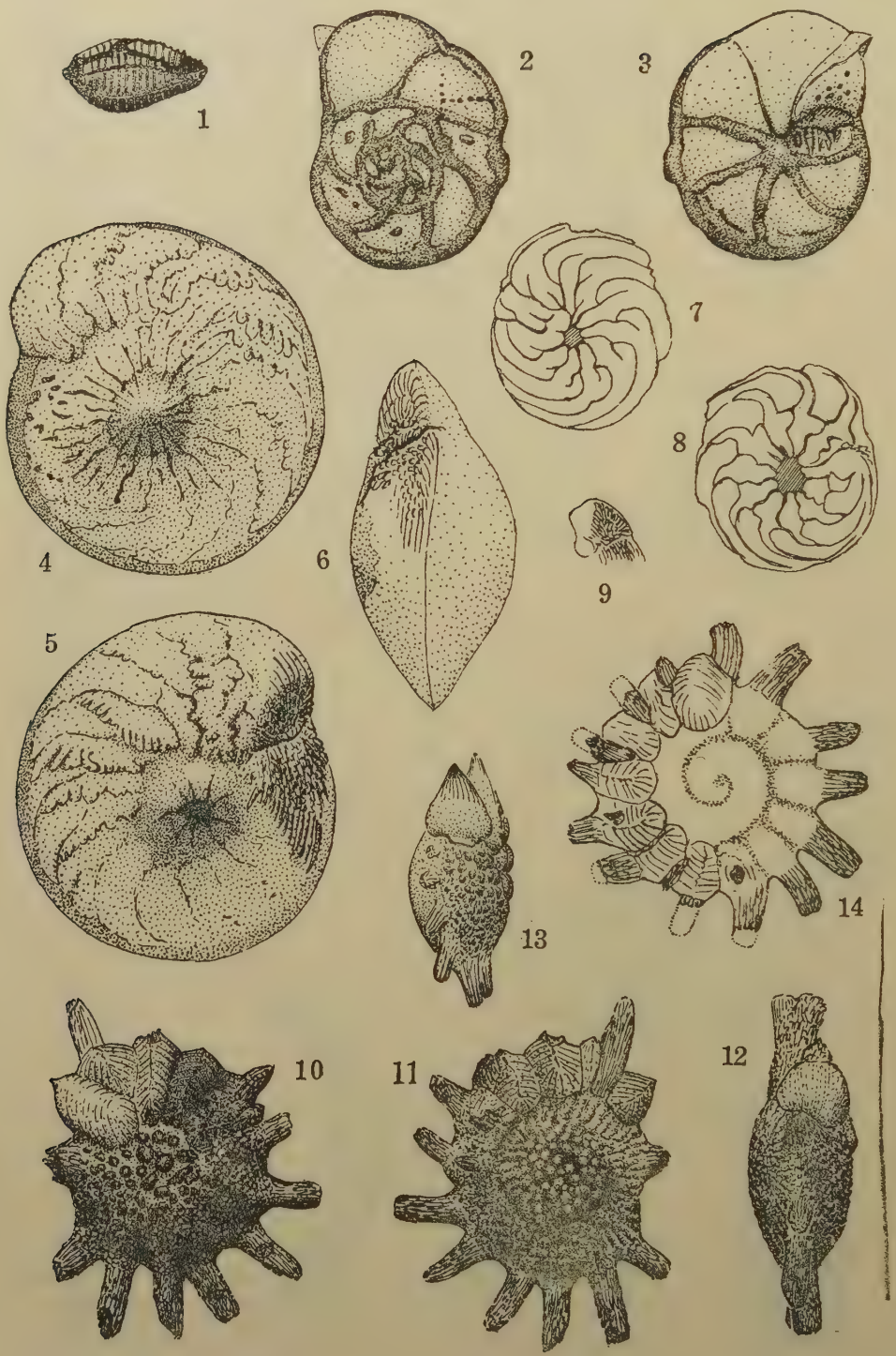
Figs. 10, 11. *Cymbaloporetta bradyi* (CUSHMAN).
Takarazima, beach sand. Max. diam., 0.6 mm.

Figs. 12, 13. *Planorbulinella larvata* (PARKER et JONES).
Takarazima, beach sand. Diam., 1.6 mm.

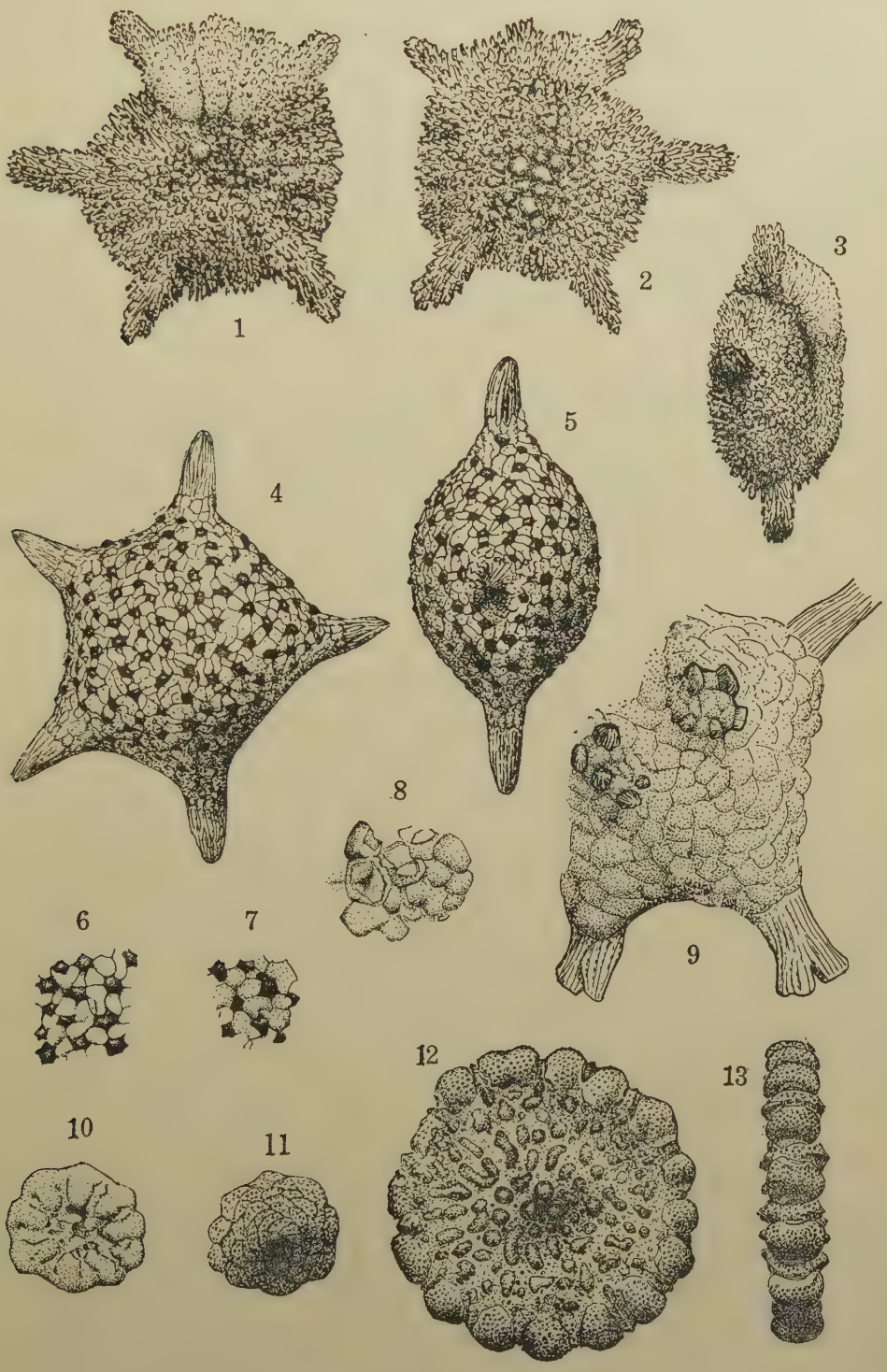
(1, 10–ventral view; 2, 11–dorsal v.; 3, 5, 13–peripheral v.; 4,9,12–side v.; 6, 7, 8, 9–surface ornamentation)



Y. Kuwano: Invertebrate Fauna of the Tokara Islands, XII.



Y. KUWANO: INVERTEBRATE FAUNA OF THE TOKARA ISLANDS, XII.



Y. KUWANO: INVERTEBRATE FAUNA OF THE TOKARA ISLANDS, XII.

NOTEWORTHY ALGAE FROM TAKARAZIMA ISLAND[1]

Eizi OGATA
Biological Department, Institute of Polytechnics, Osaka City University

With 5 Text-figures

Of the ten scattered islands of the Tokara Islands, Takarazima (Pennel or Roy Island) and Nakanosima (Pinnacle Island) were visited by a scientific expedition during the period from May 26 to June 12, 1953. The expedition, associated under the management of Mr. Yoshitaka Tsutsui, director of the Osaka Municipal Museum of Natural History, visited first Takarazima, the southernmost one (about 29° N) of this islands and next Nakanosima, nearly situated to the northern end of this islands group (about 30° N).

I was fortunately in this group of scientists and had an opportunity to collect and study marine algae in the intertidal zone of these islands. These islands had scarcely been visited by any other phycologist except T. Tanaka (1952), therefore this study was of great interest to me.

I wish to express here my hearty thanks to Dr. S. Segawa for his kind advice and to Prof. S. Miki and Dr. Y. Yoneda for their continuous encouragements.

Takarazima has well developed fringing reefs so that algal vegetation is relatively more thriving than at Nakanosima which has poor fringing reef and steep cliffs. Moreover, weather was relatively better at Takarazima than at Nakanosima in the beginning of rainy season, so algal materials collected were ample at the former island. As algal flora was in fact very poor both in vegetation and in number of species at Nakanosima, most of noteworthy algae were obtained at Takarazima mainly. Roughly comparing these two islands, the tropical feature in flora was more conspicuous at Takarazima than at Nakanosima. The feature of shore and ecological zonation of faunae and florae in the intertidal zone of Takarazima were described in detail in the paper of T. Tokioka (1953).[2] Among four noteworthy algae dealt with in the present paper, one is new to Japan.

---

1) Scientific Survey of the Tokara Islands, Report No. 24.

2) T. Tokioka: Invertebrate fauna of the intertidal zone of the Tokara Islands I. Introductory notes, with the outline of the shore and the fauna. Publ. Seto Mar. Biol. Lab., Vol. III, No. 2., Dec., 1953.

Acetabularia (Polyphysa) exigua SOLMS

(Fig. 1)

Monogr. of Acetabularia. (Trans. of Linn. Soc. London, 2nd Ser., Vol. 5, 1895) p. 28, pl. 2, figs. 1, 4; WEBER VAN BOSSE, Liste des Alg. du Siboga, Vol. 1. (1913) p. 91; YAMADA, Mar. Chlorophyc. Ryukyu (1934) p. 55.

Japanese Name. Hosigata-kasanori.

Only three specimens were collected together with abundant specimens of *Acetabularia Möbii* SOLMS on coral reef at low tide. The plant is very small. Its stem is

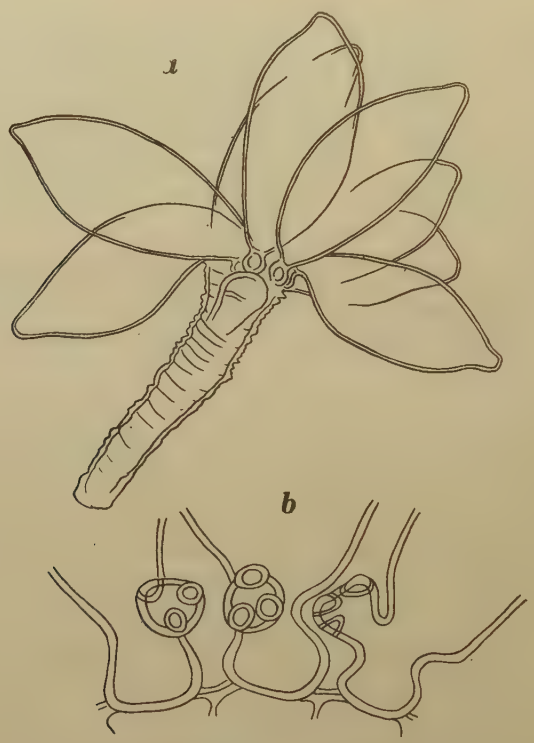


Fig. 1. *Acetabularia exigua* SOLMS.
a. Side view. ×35
b. View of the corona superior from above. ×130

solitary and 1.5–2 mm in height, and particularly in the upper part there are many dense annular furrows arranged parallel. The disc is about 2 mm in diameter and has 8–9 rays. The rays, free from each other, are-spindle shaped and have peaked tips. The corona inferior is absent. The corona superior bears three hairs or hair scars. All specimens are sterile.

Pseudobryopsis hainanensis TSENG

(Figs. 2 and 3)

Studies Mar. Chlorophyc. from Hainan (1936), p. 171 figs. 27, 28; DAWSON, Mar. Flora Isla San Benedicto Following the Volcanic Eruption of 1952–1953 (1954), p. 9, pl. 3, figs. 2–4.

Japanese Name. Hanemo-modoki (nov.).

This species has hitherto been discovered only at Hainan Island, South China, and Isla San Benedicto, on the opposite side of the Pacific Ocean. The specimens collected are only a few tufts during the sojourn at Takarazima. These were so inconspicuous that the exact habitat of the thallus was overlooked during the collecting. Presumably these were collected together with the thrived tufts of small *Bryopsis* sp. on the coral reef of intertidal zone.

Among the specimens at hand, two tufts are mature. The tuft has a few axes, which are erect, subcylindrical, maximal 2.7 mm and ordinary 1.5–2.0 mm in height, simple or rarely dichotomously branched in the upper portion, gradually tapering upward until the apex.

The ramuli, issuing on all side generally, cover the axis softly and densely except on some range of the lower portion of the axis. Simple and subcylindrical ramuli are 1.2–1.8 mm long and 31–39μ broad in the lower part, 18–23μ at the apex. At the bases they are narrowed.

The gametangium is obovate or spherical in shape and mucronated characteristically. It is borne almost singly at the basal portion of ramulus near the axis.

Fig. 2. *A tuft of Pseudobryopsis hainanensis* TSENG. ×4

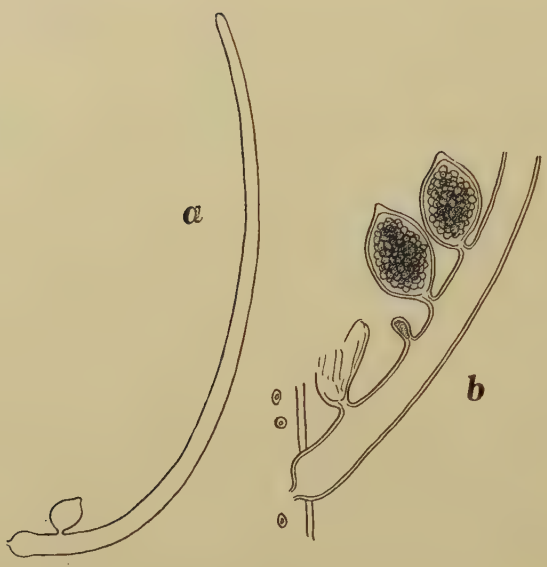


Fig. 3. *Pseudobryopsis hainanensis* TSENG.
a. A ramulus bearing a single gametangrum near its base. ×75
b. Two matured gametangium and ruptured remain on the same ramulus. ×150

Occasionally two or more gametangia and remnant bases are seen at the base of ramulus. They are 60–90μ long, 45–60μ in diameter. Pyrenoids are present in the 2–3μ broad chromatophores.

In comparison with other species of this genus, this specimen coincides well with *Pseudobryopsis hainanensis* TSENG in dimensions as shown in Table 1. As seen from the above description, however, our plant differs from his plant in having more than one gametangium on the ramulus. On the other hand, the material of Isla San Benedicto recognized as *P. hainanensis* by DAWSON (1954) also have the same feature as our plant with regards to the gametangium numbers on the ramulus. Accordingly my plant should be considered as *P. hainanensis*, and so it seems to be not infrequent that the ramuli have not only single gametangium but two or more.

Although the original specimen was described to be growing on the root of a *Rhizophora* plant by TSENG, DAWSON's plant was found on the fresh lava of San Benedicto. Mine was presumably on the coral reef together with the tufts of small *Bryopsis* sp., and there growing no *Rhizophora* plant at Takarazima. So, it is probable that this species does not always grown on the root of *Rhizophora* plant.

Table 1.

Species	Height of axis (cm)	Width of stem (μ)	Length of ramulus (mm)	Width of ramulus (μ)	Size of gametangium	
					Width (μ)	Length (μ)
Pseudobryopsis hainanensis (after TSENG, 1936)	2.2	500(lower part) 100(upper part)	1.2	30–36(lower part) 18–22(tip)	36–52	52–78
P. mauritiana (after BÖRGESEN, 1948)	10	400	1.0	70–80	125	200
P. mucronata (after BÖRGESEN, 1930)	5.0	250				
P. Myura (after BÖRGESEN, 1925)	5.0			100(lower part) 25–30(tip)	30	50
P. oahuensis (after EGEROD, 1952)	3–5	400–500	2.5	30	60–75	135–150
P. papillata (after NASR, 1944)	15	1000	4.0	50	50–65	70–90
P. parva (after DAWSON, 1954)	0.5–0.7	100(at the base) 25–15(tip)	1.0–1.5	20	35–50	190
Present specimen	2.7 (max.)	700(lower part) 300(upper part)	1.8	31–39(lower part) 18–23(tip)	45–60	60–90

Coelarthrum coactum OKAMURA et SEGAWA

(Fig. 4)

SEGAWA, Mar. Alg. Susaki, Prov. Izu, II (1936), p. 186, fig. 7.

Japanese Name. Sujiko-nori (nov.)

Though all sterile, somewhat numerous materials, drifted ashore by storm, were collected.

The present specimens almost agree with the description and illustration given by SEGAWA (1936) in every way, although different in some points.

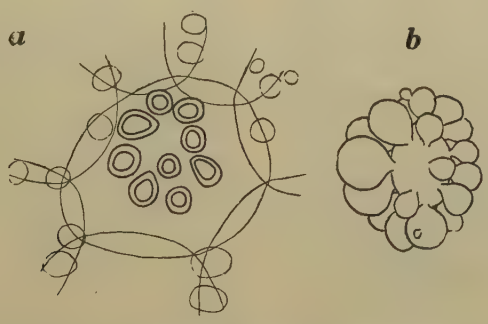


Fig. 4. *Coelarthrum coactum* OKAMURA et SEGAWA.

a. Gland cells ornated on inner large cells seen from the cavity. ×200

b. Specimen somewhat regularly ramified. ×1

In the specimens at hand, the gland cells appear on normal large cells usually more numerous than in his plant. There exist, of course, such gland cells as described in the original paper. Furthermore, the mode of ramification in the frond of one specimen is rather regular, that is, small vesicles issue from the central large one somewhat radially. Near the diaphragms, the membrane is composed of three sorts of layers; small 2 to 3-celled cortical layer, large one-celled middle layer and small one-celled innermost layer.

Erythrocolon podagricum (HARVEY) J. AGARDH

(Fig. 5)

YAMADA and TANAKA, Mar. Alg. Isla. Yonakuni (1938), p. 78, figs. 10–11.

Japanese Name. Hime-hukurotunagi.

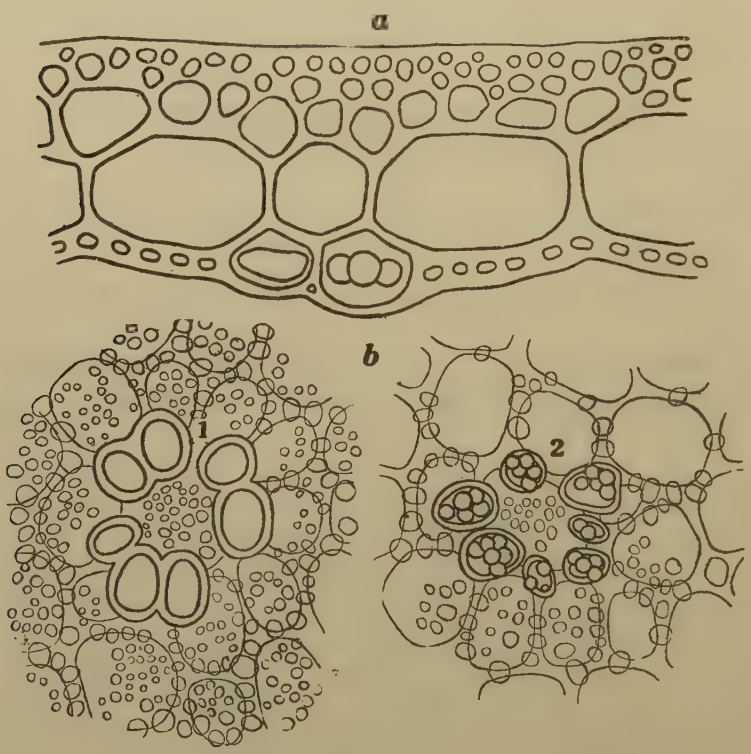


Fig. 5. *Erythrocolon podagricum* (HARVEY) J. AGARDH.
a. Transverse section of frond with two sorts of gland cells. ×300
b. Inner surface with gland cells facing the cavity. ×180
1. Ordinary gland cells. 2. Gland cells of which content is divided into granules of iridescent substance.

A few specimens from Tokara which are sterile seem to coincide well with the description and illustration of YAMADA and TANAKA.

The Tokara specimens have two sorts of gland cells. One is the same as that of the Yonakuni specimens, the other somewhat different. In gland cell of the latter, the content is divided into some iridescent granules. In the present materials also, the assemblies of ordinary gland cells, grouping in 5–8, ornated on the cell of innermost layer, are frequent and those in form of the latter sort are rare. In a few cases these two sorts of gland cells are found mixed in one colony.

ON A COLLECTION OF *GARDNERULA CORYMBOSA* (HARVEY) J. DE TONI[1)]

Isamu UMEZAKI
Department of Fisheries, Faculty of Agriculture, Kyoto University

With one Text-figure

The establishment of *Gardnerula*, one of the genera of Rivulariaceae, is by J. de Toni in 1936. According to the International Rules of Nomenclature in the Third International Botanical Congress at Brussel in 1910, the starting points for names of the Nostocaceae heterocysteae is with Bornet & Flahault's Révision des Nostocacées hétérocystées (1886–1888). However, basing upon the revised rules by the International Botanical Congress at Cambridge in 1930, J. de Toni (1936) described a new combination genus *Gardnerula* into which the genus *Polythrix* which had been valid was combined, thus *Gardnerula corymbosa* (Harv.) J. de Toni was established. Under the name of *Gardnerula corymbosa* are *Microcoleus corymbosus* Harv., *Polythrix spongiosa* Zanard., and *Polythrix corymbosa* Grunow in herb. which had been placed under the species of *Polythrix corymbosa* by Bornet & Flahault (1886) and *Sirocoleum Jensenii* Weber van Bosse (1926) which had been a species of Lyngbyae, Oscillatoriaceae, made as a synonym respectively. The genus *Polythrix* was established by G. Zanardini in 1872, based upon the type species *Polythrix spongiosa*. Before the genus was established, W. Harvey in 1858 reported *Microcoleus corymbosus* as a new species in his Nereis Boreali-Americana, Part III. Afterwards, E. Bornet & C. Flahault in 1886 ascertained from A. Grunow's Herbarium *Polythrix corymbosa* into which *Microcoleus corymbosus* was combined, and under the new combination species they placed *Polythrix spongiosa* given by G. Zanardini as a synonym.

Since then little attention has been attracted to the genus *Polythrix* by phycologists. However, J. Tilden (1910) and L. Geitler (1932) enumerated *Polythrix corymbosa* (Harv.) Grunow in their books respectively. In 1926, A. Weber van Bosse described a new species *Sirocoleum Jensenii* whose trichome is distinctly tapering into a hair at its apex and possesses cylindrical heterocysts, and he placed it in the family Oscillatoriaceae. Afterwards, as above mentioned the species was combined into the genus *Gardnerula* by J. de Toni.

In 1952 the writer reported a list of marine Cyanophyceae from the Shirahama

1) Contributions from the Seto Marine Biological Laboratory, No. 281.

coast of Wakayama Prefecture. He has kept on studying unidentified specimens collected on that opportunity in 1951, and has discovered a noteworthy species of *Gardnerula corymbosa* (HARV.) J. DE TONI which is a new record for the Japanese flora. Furthermore he had collected in great abundance well matured specimens of the species in April 1955, when he had an opportunity for collecting the marine Cyanophyceae of Amami-Oshima of Kagoshima Prefecture, the southernmost island in Japan. The frond from Shirahama was found growing among the strata of other algae mixed with fine sand, on rocks in the upper littoral zone. The frond is yet young and is much smaller, measuring a range from 150 μ to 1300 μ high. The trichome, however, is rather thicker, 7.5–16.5 μ in diameter at its base and 4.5–12 μ in diameter at its middle. On the other hand, the alga from Amami-Oshima was found on rocks in the upper littoral zone or along the high tide level, forming velvety strata widely expanded, and the frond is 4–7 mm in height, well matured, forming abundant hormogonia in the apical portion of the branch. In size the frond from Amami-Oshima corresponds with the descriptions of *Microcoleus corymbosus* by HARVEY and of *Sirocoleum Jensenii* by WEBER VAN BOSSE. The diameter of the trichome is 7–15 μ, mostly 9–12 μ at its base, 5–13 μ, mostly 6–9 μ at its middle. On the whole, the Amami-Oshima specimen, except the height of frond, is much the same as that of Shirahama. ZANARDINI's original diagnosis of *Polythrix spongiosa* is as follows: Frondibus lineam altis, 1/40‴ crassis; filis tenuissimis, 1/900‴ crassis. According to HARVEY the fronds of *Microcoleus corymbosus* HARV. are described to be from a eighth to a quarter of an inch in length. In the diagnosis of *Polythrix corymbosa* GRUNOW, BORNET & FLAHAULT (1886) described that the thallus is 1–3 cm high and the trichome is 5–6 μ in diameter. In *Sirocoleum Jensenii* WEBER VAN BOSSE the frond is 1 cm high, the filament 120–260 μ broad and the trichome 3.6–5.4 μ broad, rarely 7.2 μ. Generally in the Japanese materials the trichomes are somewhat thicker.

For the determination of this alga the writer sent the specimens from both Shirahama and Amami-Oshima to Dr. F. DROUET asking his opinion. He kindly wrote the writer that they are exactly included under the specific name of *Gardnerula corymbosa* (HARV.) J. DE TONI and sent to the writer many specimens from Bermuda, Jamaica, Israel, the Hawaiian Islands and the Philippines; with those the Japanese specimens accorded very well. All of these fronds are up to 4 mm in height and the trichome 3–12 μ, mostly 5–7.5 μ in diameter at the middle.

In both Shirahama and Amami-Oshima specimens, the intercalary heterocysts are formed not only in old plants but also in young ones and mostly cylindrical, rarely quadrate in shape, having a length of 10 μ to 25 μ. Because the frond from Amami-Oshima was adult and well matured, numerous hormogonia were found at the apical portion of the branch, single or two within a sheath, being short- or long-cylindrical. Because of still being young in Shirahama specimen their formation could not be found.

It seems that the reproduction of this species is performed by means of the

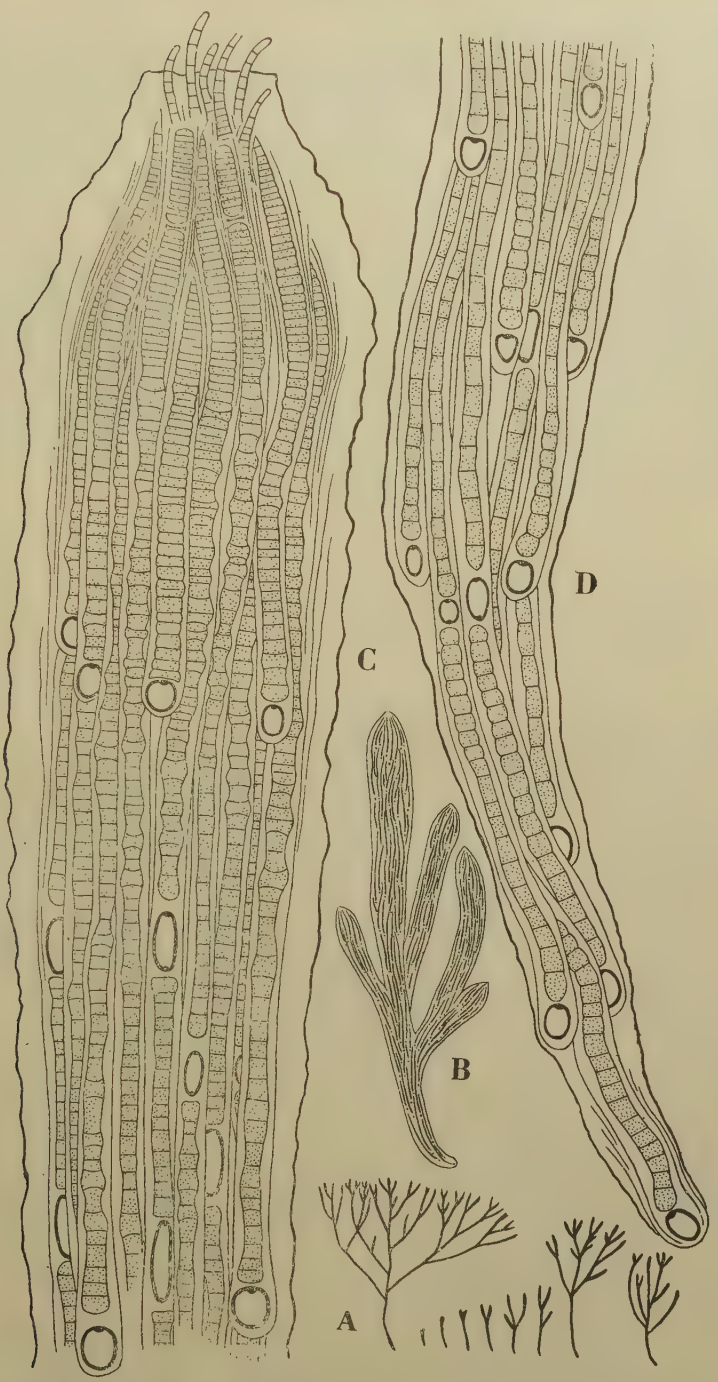


Fig. 1. *A*, habit showing the various stages of fronds. ×3. *B*, frond showing the arrangement of the filaments. ×25. *C*, apical portion of the branch of a frond. ×240. *D*, basal portion of a frond. ×240.

hormogone and the fragmentation of the branch. The frond is branched dichotomously or irregularly, and later the branched small parts fall apart from the matured main frond, and grow into new individuals. It is often found that by slight mechanical pressure the branches are readily falled apart from the main frond.

From the characteristics that the trichome is tapering into a hair at the apex and has a basal heterocyst, the genus *Gardnerula* may be placed in the family Rivulariaceae as reported by BORNET & FLAHAULT (1886), FORTI (1907), TILDEN (1910), GEITLER (1932) and DROUET (1951). Among the genera of that family the present genus may be placed between *Rivularia* and *Dichothrix* rather than between *Dichothrix* and *Calothrix* because of the feature that the repeatedly branched filaments are radiating from the base upwards in a frond. But the genus *Gardnerula* is considered quite distinct from the genus *Rivularia* by the peculiarly branched frond. Apparent differences from the genus *Dichothrix* lies both in the most simple frond and in enclosing compactly arranged numerous filaments in the frond.

Gardnerula J. DE TONI 1936

(Syn. *Polythrix* ZANARDINI 1872)

Gardnerula corymbosa (HARVEY) J. DE TONI 1936

Syn. *Microcoleus corymbosus* HARV. 1858; *Polythrix spongiosa* GRUN. in herb. in BORN. & FLAH. 1886; *Sirocoleum Jensenii* WEBER VAN BOSSE 1926.

Fronds dark blue-green, widely expanded and forming velvety strata on rocks, subdichotomously or irregularly branched, 4–7 mm in length, 30–80 μ in diam. at the basal portion, 60–300 μ in diam. at the branched upper portion; common teguments thick, somewhat gelatinous, rough on the outer surface, hyaline, but the inner part yellowish or light brown, lamellated; filaments repeatedly branched from the base upwards, tight-parallel; sheaths of filaments hyaline, but above often light brown, lamellated, divergent; trichomes blue-green, somewhat thicker at the base, 7–15 (mostly 9–12) μ in diam. at the base, 5–12 (mostly 6–9) μ in diam. at the middle, above tapering gradually or abruptly into a long or somewhat short hyaline hair; cross walls constricted or not; cells generally shorter above, 3–7.5 μ in length, 1–1/4 time as long as the diameter, below longer, 4–16 μ in length, 3–1/3 times as long as the diameter; heterocysts basal, often both basal and intercalary; the basal ones single, 6.5–15 μ in diam., hemispherical, spherical or ellipsoidal; intercalary ones single, rarely two in series, mostly cylindrical or ellipsoidal, 10–25 μ in length, a little thicker than the diameter; hormogonia one or two within the sheath, 15–30 μ in length.

Japanese name: Ōhigesō (n. n.).

Hab.: On rocks in the upper littoral zone or along the high tide level. Koniya, Amami-Oshima, Kagoshima Pref. April 10 & 11, 1955. Nos. 1787, 1798, 1799, 1800, 1801, 1802 (in Herb. UMEZ.); growing among the strata of other blue-green Algae mixed with sand, in the upper littoral zone. Seto, Shirahama, Wakayama Pref.

November 2, 1951. No. 550 (in Herb. UMEZ.).

Distribution: North America (Florida), Atlantic Ocean (Bermudas), Pacific Ocean (Hawaii, Tongatabu, Kei, Philippines), Malay (Singapore), Mediterranean (Israel), West Indies (Jamaica).

The above description is based upon the materials collected at Koniya in Amami-Oshima.

Sincere thanks are expressed to Dr. Y. YONEDA of the Department of Fisheries, Faculty of Agriculture, Kyoto University, and the writer is indebted to Dr. F. DROUET of the Chicago Natural History Museum at Chicago, Illinois, the United States, who gave him valuable suggestions and a number of specimens of *Gardnerula corymbosa*. Thanks are also due to Dr. H. UTINOMI of the Seto Marine Biological Laboratory of Kyoto University, who kindly gave him much conveniences in collecting materials of this research, in the year of 1951.

LITERATURE CITED

BORNET, E. et C. FLAHAULT 1886. Révision des Nostocacées hétérocystées, Ann. Sc. Nat. VII. Bot., vol. 3, p. 380.

DE TONI, J. 1936. Noterelle di nomenclatura algologica. VIII. Terzo elenco di Missoficee omonime, Brescia, p. 5.

DROUET, F. 1951. Cyanophyta, in SMITH's Manual of Phycology, p. 164. Waltham, U. S. A.

FORTI, A. 1907. Sylloge Myxophycearum, in DE TONI's Sylloge algar., vol. 5, p. 645.

GEITLER, L. 1932. Cyanophyceae, in L. RABENHORST's Kryptogamen-Flora, Bd. XIV, p. 594.

HARVEY, W. H. 1858. Chlorospermeae, Ner. Bor.-Amer., Part III, p. 109, pl. 48 B.

UMEZAKI, I. 1952. Some Marine Cyanophyceae from the Shirahama Coast of Wakayama Pref., Seto Mar. Biol. Lab., vol. II, no. 2, p. 235–248.

———— 1956. Marine Cyanophyceae from Japan (12), Journ. Jap. Bot., vol. 31, no. 2, p. 33, fig. 41.

TILDEN, J. E. 1910. Myxophyceae, in Minnesota Algae, vol. 1, p. 280–281.

WEBER VAN BOSSE, A. 1926. Algues de l'expedition danoise aux ile Kei, Papers from Dr. Th. Mortensen's Pac. Exp. 1914–16, XXXIII, Vidensk. Meddel. Dansk Naturh. Foren., vol. 81, p. 68 70.

ZANARDINI, G. 1872. Phycearum Indicarum Pugillus, Mem. Rea. Inst. Veneto, vol. 17, p. 160.

RECORD OF WORKS
DONE AT THE SETO MARINE BIOLOGICAL LABORATORY

1954 (昭和29年)

Contribution
No. (Jap. No.)

ARAKI, Choji & ARAI, Kiyoshi: Studies on agar-digesting bacteria. The isolation of agar-digesting bacteria and their enzymatic activities. *Mem. Fac. Ind. Arts, Kyoto Techn. Univ., Sci. and Techn.*, 3B, pp. 7–23.

BABA, Kikutarô〔馬場菊太郎〕: *Runcina setoensis*, a new and rare species from the coast of Kii, middle Japan (Opisthobranchia). *Publ. Seto Mar. Biol. Lab.*, 3 (3), pp. 373–374. 228

————: 日本産クロスジアメフラシ亜属3種について〔Notes on the species of the genus *Notarchus* (subg. *Stylocheilus*) from Japan (Opisthobranchia)〕、動物雑〔*Zool. Mag.*〕, 63 (5), pp. 218–231. (With English rés.)

FUSE, Shinichiro, MIURA, Taizo & OKUNO, Ryonosuke〔布施慎一郎・三浦泰蔵・奥野良之助〕: マスアミによる漁獲物の終日変化〔Daily change of catches by means of "Masuami"〕. *Ibid.*, 63 (11/12), p. 493.

HABE, Tadashige〔波部忠重〕: 日本の海産貝類の分布について〔On the distribution of marine Molluscan shells in Japan〕. *Ibid.*, 63 (3/4), p. 108.

————: 内湾の貝類分布〔On the ecological distribution of Molluscan shells in inner bays〕. *Ibid.*, 63 (11/12), pp. 483–484.

————: 貝類とその生活〔*Molluscan shells and their life*〕. 82 pp., 1 pl. 恒星社〔Kôseisya〕, Tokyo.

————: Report on the Mollusca chiefly collected by the S. S. Sôyô-maru of the Imperial Fisheries Experimental Station on the continental shelf bordering Japan during the years 1922–1930. Part 1. Cephalaspidea. *Publ. Seto Mar. Biol. Lab.*, 3 (3), pp. 301–318, pl. 38. 223

HANEDA, Yata & TOKIOKA, Takasi: Droplets from the plankton net, XV. Record of a caudate form of *Pegea confoederata* from the Japanese waters, with some notes on its luminescence. *Ibid.*, 3 (3), pp. 369–371. 227

IWATA, Fumio: Some nemerteans from the coasts of the Kii Peninsula. *Ibid.*, 4 (1), pp. 33–42. 236

KAWAGUTI, Siro〔川口四郎〕: ヨツアナカシパンの緑色色素〔Green pigments of a cake urchin, *Peronella japonica* Mortensen〕. 動物雑〔*Zool. Mag.*〕, 63 (3/4), p. 138.

————: 造礁珊瑚の骨骼のアミノ酸〔Amino acid of the skeleton of a reef coral〕. *Ibid.*, 63 (11/12), p. 451.

KAWAGUTI, Siro & YAMASU, Teruhumi: Pigment cells in the perivisceral fluid of the Echinoidea. *Biol. Journ. Okayama Univ.*, 1 (4), pp. 249–260, pls. 1–2. ..... **231**

——————— & SAKAMOTO, Daigoro: Pigment of skeleton of a reef coral, *Oulastrea crispata*. *Ibid.*, 1 (4), pp. 265–270. ..... **232**

KURODA, Tokubei & HABE, Tadashige〔黒田徳米・波部忠重〕: On some Japanese Mollusca described by A. Adams, whose specimens are deposited in the Redpath Museum of Canada (No. 1). 貝類雑〔*Venus*: *Jap. J. Malac.*〕, 18 (1), pp. 1–16, pls. 1–2. ..... **233**

——————— & ———————: New aquatic gastropods from Japan (日本産水棲新巻貝). *Ibid.*, 18 (2), pp. 71–79, (With Japanese rés.) **247**

——————— & ———————: Notes on three remarkable species of Japanese gastropods (珍奇なる日本産腹足類3種について). *Ibid.*, 18 (2), pp. 79–84. (With Japanese rés.) **248**

——————— & ———————: New genera of Japanese marine gastropods (日本産海産腹足類の新属). *Ibid.*, 18 (2), pp. 84–97. ..... **249**

MIYADI, Denzaburo〔宮地伝三郎〕: 動物生態学〔Zoological ecology〕. 動物雑〔*Zool. Mag.*〕, 63 (8/9), pp. 348–352.

——————— & HABE, Tadashige: Biological successions in disharmonic bays and lagoons, and their improvement for fisheries purposes. *Proc. Seventh Pacific Sci. Congress*, 4, pp. 477–479.

———————, KURODA, T. & HABE, T.: 日本近海の生物地理区について〔On marine biogeographical areas of Japanese coast〕, 生物科学〔*Biol. Sci.*〕, 5 (4), pp. 145–148.

———————, YAMAZI, I. & FUSE, Sh.: 美保湾・中海の海況と生物群集, 2〔Oceanographical conditions and biotic communities of Miho Bay and Nakano-umi, 2〕. 京都大学生理生態学研究業績〔*Contr. to Physiol. and Ecol., Kyoto Univ.*〕, No. 78, pp. 1–18, pls. 1–25. ..... (Jap. **81**)

MORI, Syuiti & ONDO, Yoshinori〔森 主一・恩藤芳典〕: ウミシヤボテンの日週期活動の光による制御〔Control of daily rhythmic activities of *Cavernularia obesa* Val. by light〕. 動物雑〔*Zool. Mag.*〕, 63 (11/12), p. 499.

OHGUSHI, Ryuichi〔大串龍一〕: 笠貝の帰家習性について〔On the homing habit of limpets〕. *Ibid.*, 63 (3/4), pp. 96–97.

——————— : 潮間帯にすむ笠貝の習性, I. 2種の笠貝の活動と潮汐との関係〔Ethological studies on the intertidal limpets, I. On the tidal rhythmic activities of two species of limpets〕. 日生態会誌 (*Jap. J. Ecol.*〕, 4 (3), pp. 120–122. (With English rés.) ..... (Jap. **83**)

——————— & MIURA, T.: 笠貝の帰家行動について〔On the homing behavior of limpets〕. 南紀生物〔*Nanki Seibutsu*〕, 5 (1), pp. 21–24, 30. ... (Jap. **82**)

ONDO, Y. & MORI, S.: フナムシ *Ligia exotica* の日週期活動, I. 野外でみられた移動群の行動を中心にみた週期活動〔Daily rhythmic activity of *Ligia*

exotica Roux, I. Periodic behavior of migratory group under natural conditions〕. 動物雑〔*Zool. Mag.*〕, 63 (11/12), p. 499.

ÔYAMA, Katura, YAMAMOTO, Torao & TOKIOKA, Takasi: Invertebrate fauna of the intertidal zone of the Tokara Islands, VIII. Molluscan shells. *Publ. Seto Mar. Biol. Lab.*, 4 (1), pp. 1–15. .....**234**

SHIINO, Sueo M.: Copepods parasitic on Japanese fishes, 3. On two new species of the genus *Anuretes*. *Rep. Fac. Fish., Pref. Univ. Mie*, 1 (3), pp. 260–272.

————: Ditto, 6. Two species of the family Cecropidae. *Ibid.*, 1 (3), pp. 333–345.

————: On a new copepod, *Caligus caltomi* n. sp., parasitic on the fish, *Caltomus japonicus* (C. & V.). *Bull. Jap. Soc. Sci. Fish.*, 20 (1), pp. 16–20.

TAKEDA, Nobuyuki〔武田信之〕: 海産橈脚類 *Tigriopus japonicus* Mori における温度適応〔Thermal adaptation in the marine copepod, *Tigriopus japonicus* Mori〕. 生理生態〔*Physiol. & Ecol.*〕, 6 (1), pp. 49–54. (With English rés.) .....(Jap. **84**)

TOKIOKA, Takasi〔時岡 隆〕: トカラ列島調査資料: 海産無脊椎動物俗名語彙〔Glossary of local names of marine invertebrate animals in the Tokara Islands〕. 南紀生物〔*Nanki Seibutsu*〕, 5 (1), pp. 5–15.

————: Invertebrate fauna of the intertidal zone of the Tokara Islands, VII. Ascidians (Contributions to Japanese Ascidian fauna, VII). *Publ. Seto Mar. Biol. Lab.*, 3 (3), pp. 239–264, pls. 18–37. .....**222**

————: Droplets from the plankton net, XIII. Emergence of a dense patch of chaetognaths near the Laboratory, XIV. Record of a scyllarid *Phyllosoma* near Seto. *Ibid.*, 3 (3), pp. 359–368, pls. 41–43. .....**226**

————: Contributions to Japanese Ascidian fauna, VIII. Sporadic memorandum (1). *Ibid.*, 4 (1), pp. 67–68, pl. 3. .....**239**

————: Ditto, IX. Re-description of Oka's species found in "Figuraro de Japanaj Bestoj." *Ibid.*, 4 (1), pp. 69–74, pl. 4. .....**240**

————: Ditto, X. Notes on some ascidians collected in Osaka Bay (2). *Ibid.*, 4 (1), pp. 75–98, pls. 5–8. .....**241**

————: Droplets from the plankton net, XVI. On a small collection of chaetognaths from the central Pacific. *Ibid.*, 4 (1), pp. 99–102. .....**242**

————: Descriptions of the aggregated form of *Brooksia rostrata* (Traustedt), an insufficiently known salpa. *Ibid.*, 4 (1), pp. 147–153, pls. 9–10. .....**246**

————: プランクトン〔Plankton〕. 動物雑〔*Zool. Mag.*〕 63 (8/9), pp. 325–326.

————: ムラサキウニ〔*Anthocidaris crassispina* (A. Agassiz)〕. 生物学実験法講座〔*Series of Techniques in biological Researches*〕, 5 (A_1), pp. 1–18, pls. 1–14. 中山書店〔Nakayama Syoten〕, Tokyo.

TSUKUDA, Hiroko & OHSAWA, Wataru〔佃　弘子・大沢　済〕: 塩類にたいするタマキビの反応〔Response of the periwinkle to salts〕. 動物雑〔*Zool. Mag.*〕, 63 (11/12), p. 498.

UMEZAKI, Isamu〔梅崎　勇〕: 日本海産藍藻類 (10)〔Marine Cyanophyceae from Japan (10)〕. 植研雑〔*Journ. Jap. Bot.*〕, 29 (6), pp. 172–176.

UTINOMI, Huzio〔内海冨士夫〕: The fauna of Akkeshi Bay, XIX. Littoral Pycnogonida. *Publ. Akkeshi Mar. Biol. Sta.*, No. 3, pp. 1–28, pl. 1. .....**221**

———: *Dendronephthya* of Japan, II. New species and new records of *Dendronephthya* and the allied *Stereonephthya* from Kii region. *Publ. Seto Mar. Biol. Lab.*, 3 (3), pp. 319–338, pls. 39–40. .....**224**

———: A check list of echinoids found in the Kii region. *Ibid.*, 3 (3), pp. 339–358. .....**225**

———: Invertebrate fauna of the intertidal zone of the Tokara Islands, IX. Cirripedia. *Ibid.*, 4 (1), pp. 17–26. .....**235**

———: Some Alcyoniid octocorals from Kii coast, middle Japan *Ibid.*, 4 (1), pp. 43–55, pl. 1. .....**237**

———: Some Nephtheid octocorals from Kii coast, middle Japan. *Ibid.* 4 (1), pp. 57–66, pl. 2. .....**238**

———: Coral-dwelling organisms as destructive agents of corals. *Proc. Seventh Pacific Sci. Congress*, 4, pp. 533–536.

———: On a small collection of Anthozoa from the Inan coast, Ehime Prefecture. *Mem. Ehime Univ., Sect. II (Sci.), Ser. B (Biol.)*, 2 (1), pp. 101–106.

———: 琉球列島における岩礁性フジツボ類の分布と隔離〔Distribution and isolation of rocky reef barnacles in the Ryukyu Islands〕. 動物雑〔*Zool. Mag.*〕, 63 (11/12), p. 474.

———: 海産動物採集法〔Methods of collecting marine animals〕. 生物学実験法講座〔*Series of Techniques in biological researches*〕, 2 (A), pp. 1–39. 中山書店〔Nakayama Syoten〕, Tokyo.

YAMADA, Mayumi〔山田真弓〕: タカアシガニ附着の多毛環虫類〔Polychaetous annelids found on the giant crab, *Macrocheira kaempferi* (de Haan)〕. 動物雑〔*Zool. Mag.*〕, 63 (11/12), p. 473.

YAMAZI, Isamu〔山路　勇〕: 新大和堆附近のプランクトンについて〔On the plankton collected near Sin Yamato Bank in the Sea of Japan〕. *Ibid.*, 63 (3/4), p. 101.

———: Plankton investigation in inlet waters along the coast of Japan, XI. The plankton of Kozima Bay in the Seto Naikai (Inland Sea). *Publ. Seto Mar. Biol. Lab.*, 3 (3), pp. 399–421. .....**229**

———: Ditto, XII. The plankton of Miyako Bay on the eastern coast of Tôhoku district. *Ibid.*, 3 (3), pp. 423–441. .....**230**

———: Ditto, XIII. The plankton of Obama Bay on the Japan Sea coast. *Ibid.*, 4 (1), pp. 103–114. .....**243**

YAMAZI, Isamu: Ditto, XIV. The plankton of Turuga Bay on the Japan Sea coast. *Ibid.*, 4 (1), pp. 115–126. .....**244**

————: Ditto, XV. The plankton of Yosa-Naikai and Kumihama Bay, enclosed bays on the Japan Sea coast. *Ibid.*, 4 (1), pp. 127–145. .....**245**

CORRIGENDA

in **RECORD OF WORKS** for 1953 (Publ. Seto Mar. Biol. Lab., vol. 4, no. 1, pp. 155–158).

p. 156, line 20. Read 動物雑〔*Zool. Mag.*〕 for *Ibid.*

PUBLICATIONS OF THE SETO MARINE BIOLOGICAL LABORATORY

Volume I

No. 1 (Article 1). (out of print) ..... issued on May 31, 1949.
No. 2 (Article 2 to 4) ..... issued on December 25, 1949.
No. 3 (Article 5 to 9) ..... issued on October 5, 1950.
No. 4 (Article 10 to 14) ..... issued on May 31, 1951.

Volume II

No. 1 (Article 1 to 2) ..... issued on October 20, 1951.
No. 2 (Article 3 to 21 and record of works between 1922 and 1951) (Jubilee number) ..... issued on October 5, 1952.

Volume III

No. 1 (Article 1 to 8) ..... issued on July 30, 1953.
No. 2 (Article 9 to 21 and record of works for 1952) ... issued on December 20, 1953.
No. 3 (Article 22 to 32) ..... issued on May 30, 1954.

Volume IV

No. 1 (Article 1 to 14 and record of works for 1953) ... issued on November 20, 1954.
Nos. 2 & 3 (Article 15 to 35) ..... issued on May 30, 1955.

Volume V

No. 1 (Article 1 to 7) .....issued on December 20, 1955.

昭和31年6月25日印刷
昭和31年6月30日発行

非賣品

編集兼発行者
瀬戸臨海実験所
和歌山県西牟婁郡白浜町
電話白浜温泉47番

印刷所 日本印刷出版株式会社
大阪市福島区亀甲町2丁目62

印刷者 小林積造
大阪市福島区亀甲町2丁目62